Distribution and Habitat Use of Steelhead and other Fishes in the Lower Feather River, 1999-2001

Interim Report

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Summary

From 1999 to 2001, DWR conducted an intensive steelhead study in the Feather River below Oroville Dam. Investigations sought to describe characteristics of the wild steelhead population, and identify factors potentially limiting steelhead success in the lower Feather River. Habitat, water temperature, flow conditions, predation, and food availability were all considered potentially important factors. To address these topics we applied multi-scale snorkeling surveys and seining. Results show that most steelhead spawning and early rearing occurs at the upstream end of the low flow channel (LFC), near the Feather River Hatchery. In-river spawning by hatchery steelhead in the vicinity of the Feather River Hatchery may explain this skewed distribution. Over time juvenile steelhead disperse to suitable habitats throughout the LFC, especially cover-rich side channels. Steelhead rearing in the downstream portion of the LFC appeared to grow faster, and were generally larger than fish further upstream. Age-0 steelhead abundance declined throughout the summer in each survey year. This decline suggests that relatively few age-0 steelhead remain in the Feather River through their first year. Age-1 and age-2 sized steelhead trout (or resident rainbow trout) were relatively rare. Since LFC water temperatures and flow conditions appear suitable for steelhead, the apparently low production of juveniles suggests other limiting factors. For example, side channels and tributaries seem to provide the best rearing habitat in large, low elevation rivers, and yet these habitats are rare in the lower Feather River.

Introduction

The rivers of California's Central Valley have been extensively dammed and modified to provide water storage, flood control and power generation (Mount 1995). Nearly all major, west slope tributaries are presently impounded by large dams located along the transition between the Central Valley and upland, foothill regions. The resulting alteration in flow regime, water temperature, and geomorphic process (Ward and Stanford 1983, Ligon et al. 1995) has had a large impact on downstream fish communities (Brown 2000, Brown and Ford 2002, Moyle 2002). Anadromous salmonids have been most severely affected. Chinook salmon *Oncorhynchus tshawytscha* and steelhead *Oncorhynchus mykiss*, which historically ranged far into watersheds of the Sierra Nevadas (Yoshiyama et al. 1996), are now forced to complete their life history in habitat remaining below dams.

Despite these negative impacts, dams provide a potentially powerful tool for enhancing remaining stream ecosystems and fish communities. River flows and temperatures, for example, can be manipulated to create conditions more suitable for salmonid spawning and rearing. However, effective management of dam operations and implementation of any associated restoration activities requires a thorough understanding of how river conditions and habitats affect the distribution, abundance and behavior of downstream fish communities. Salmon have typically been the focus of such studies. However, this emphasis on salmon may be misplaced, since the freshwater life history phase is brief relative to steelhead, which spend several years in freshwater prior to migrating seaward (McEwan 1999). This extended residence means that habitat requirements for steelhead (e.g. river flows and temperatures) are more difficult to meet, particularly in summer months.

In California, relatively little effort has been devoted to the study of wild steelhead populations. Shapovalov and Taft's (1954) treatise on Waddell Creek is undoubtedly the most complete source of information, but since this study took place on a small, unregulated coastal river, it does not apply well to Central Valley rivers. Historic (1940-1960) adult steelhead harvest, migration timing and age composition make up the bulk of available information for Central Valley rivers (reviewed by McEwan 1999). Although largely unpublished, widespread rotary screw trap emigration monitoring in the Central Valley has provided some valuable data on the distribution and occurrence of steelhead smolts. However, we are unaware of any published study which addresses the abundance, distribution and rearing habitats of juvenile steelhead in a Central Valley river.

Typically, relationships between fish populations and habitat conditions have been conducted at fine spatial scales (Bayley and Li 1992). However, there is increasing evidence and sentiment among stream ecologists that better understanding of fish ecology and habitat relationships requires a multi-scale approach (see review by Fausch et al 2002). Central to this approach is the idea that the spatial arrangement and connectivity of critical habitats for each life history phase (spawning, rearing, feeding, refugia from stressors) strongly affects the persistence, abundance and productivity of fish populations (Schlosser 1991, 1995). A coarser spatial resolution may suggest patterns of population regulation that would not be apparent at finer spatial scales. Microhabitat data alone would likely miss these landscape scale population constraints, and might exaggerate the importance of other fine scale habitat variables.

In our studies of the Feather River downstream of Oroville Dam, we implemented a multi-scale sampling program akin to those discussed by Fausch et al (2002). In this report we present data from three years of snorkeling studies, focusing on juvenile steelhead, but including other species. Our purpose is to: (1) provide information on the seasonal distribution, relative abundance, and habitat use of common Feather River fishes, particularly salmonids; and (2) identify river conditions, habitats, or ecological interactions which may limit the abundance of salmon and steelhead.

The Oroville Dam-Thermalito Complex on the Feather River is under review for re-licensing by the Federal Engery Regulatory Commission (FERC). The FERC re-licensing provides an opportunity to evaluate project effects on downstream fish communities and develop potential enhancement measures. Furthermore, the unusual design of flow release structures from the Oroville-Dam Thermalito Complex provides a unique setting to evaluate the relative importance of habitat, temperature and flow regime on fishes. The findings may be especially pertinent as California considers and designs restoration activities for its regulated rivers.

Study Area

The Feather River drainage is located in the Central Valley of California, draining approximately 9,324 km^2 of the western slope of the Sierra Nevada (Figure 1). Where it leaves the foothills, the Feather River is impounded by Oroville Dam, completed in 1967. Lake Oroville has a capacity of about 430,000 hectare-meters of water, and is the centerpiece of the State Water Project, the principal water storage and conveyance system operated by the State of California. Under normal operations, the majority of water released from Lake Oroville is directed into the Thermalito Complex (Figure 1). Except for local water diversions, the rest is returned to the Feather River through Thermalito Afterbay Outlet (TAO), then flows southward through the valley to the confluence with the Sacramento River at Verona. The remainder of releases from Lake Oroville, typically 17 m^3/s (cms), runs through the historic river channel locally known as the low flow channel (LFC).

Field activities occurred in a 37 km river segment between the Fish Barrier Dam, which diverts salmon and steelhead into the Feather River Fish Hatchery, and Honcut Creek. This portion of the river is composed of two distinct river segments that differ in physical and environmental conditions. The LFC extends from the Fish Barrier Dam at river kilometer (rkm) 108 to the TAO (rkm 95). Flow regime in the LFC is stable, exceeding 17 cms only during flood events. LFC temperature regime, channel morphology, and geomorphic process are strongly influenced by the proximity to Oroville Dam and the city of Oroville, which is separated from the river by flood control levees. In summer months, water temperatures in the LFC are cooler than those downstream, and generally do not exceed a mean daily maximum of 18.3°C at rkm 99.8. The high flow channel (HFC), which extends from the TAO to Honcut Creek (rkm 69), is subject to diverse thermal, hydrologic and geomorphic conditions. Because the HFC is further downstream, water temperatures are influenced less by dam releases and exhibit more diel and seasonal fluctuations. Flow regime in the HFC is more variable, driven by flood control and water storage operations at the Oroville Dam and Thermalito Complex. The river below Thermalito Outlet is generally less confined by levees, with a broader active channel and floodplain, than the LFC. However, both the LFC and HFC river segments are very low gradient.

Methods

Field sampling

Snorkel surveys were conducted at three spatial scales: broad (25 km), intermediate (300-500 m), and fine (25m). Broad scale surveys covered the study area from the Fish Barrier Dam to Gridley Bridge (rkm 81.8) and occurred only once per year. Broad scale surveys were completed annually in 1999, 2000, and 2001. The 1999 survey was conducted from 5/13 to 5/26; the 2000 survey from 6/5 to 6/20; and the 2001 survey from 5/1 to 5/10. These surveys provided a snapshot of overall abundance and distribution of fishes in the lower Feather River, and provided observations in areas or habitats not covered at smaller scales. Snorkel observations were generally made in a downstream direction, as currents were often strong. Three to six divers were distributed among three transects: left bank, right bank and center channel. Divers used plastic dive slates to mark information on individual fish or schools of fish located. Groups of similar sized fish that were observed in a 1 m^2 or less area were treated as a single observation.

Data recorded included: the approximate fish size (mm fork length), number of fish, substrate type, cover, and habitat type (hydrogeomorphic units). Fish identification and size estimation by divers was verified and calibrated by training with tethered fishes in a controlled setting, and also by oversight of experience divers. Size estimation was also aided by comparing observed fishes to nearby objects. These objects could then be measured using the scale provided on plastic writing slates. The classification system for substrate, cover and habitat are provided in Tables 1, 2 and 3, respectively. Effort at each sampling site was recorded in terms of the time sampled, area covered and the number of divers.

Intermediate-scale surveys occurred monthly from March through August during each study year. These surveys covered nine permanent sampling stations, six in the LFC and three in the HFC, each with at least one riffle-pool sequence. Observations of fish and habitat were performed as previously described for broad-scale surveys. Additionally, depth, velocity, substrate, cover and habitat types were measured in ten systematic transects at each station. This information was used to describe and quantify available habitat. The quantity and boundaries of hydrogeomorphic units (riffles, glides, pools and backwaters) for the entire study area were based on aerial photographs (1998) and on the ground observations. The linear extent of riffle, glide and pool habitat was measured from the resulting maps. A summary of the habitat characteristics of each site is in Table 4.

Fine-scale surveys were completed monthly from March through August 2001 to provide replicated samples. Twenty-four sampling locations were selected at random and sampled each month, twelve each in the LFC and HFC. Each section covered an area 25 meters long and 4 meters wide and ran parallel to one river bank. Two divers surveyed the reach by working upstream and marking the number, species, size and position of all fishes observed. After the fish survey was complete, divers recorded water depth, average velocity, substrate, cover and habitat types at 36 points, each representing a 1 m^2 cell within the reach. Fish observations were recorded by their association with these 1 m^2 cells. Depth and focal velocity were also recorded for each fish observation. For all surveys, water temperatures were monitored continuously by a network of StowAway© electronic thermistors.

In June and July of 2002, intensive seine sampling was conducted at four sites in the LFC. This sampling was performed in association with a mark-recapture study of juvenile steelhead to document residence time, movements and growth rate. The four sites sampled were (from upstream to downstream): Hatchery Ditch (rkm 107), Bedrock Riffle (rkm 106.1), Matthews Riffle (rkm 103.2), and Steep Riffle (rkm 98.2). Seining samples consisted of numerous, short, sweeping hauls. Short, rapid seine hauls were necessary because of swift currents and the inherent patchiness of suitable steelhead habitat. A maximum of 50 linear meters was sampled at each location and visit. All steelhead captured were weighed, measured (fork length) and uniquely marked with a photonic color tagging gun. Steelhead recaptured with photonic color tags were recorded by tag code description. After measurement and marking, fish were returned to the river in the approximate location of their original capture.

Data analysis

Based on length frequency data, steelhead less than 100 mm fork length were classified as age-0, while steelhead greater than 100 mm FL were designated as juvenile/adult (age-1+). No size categories were used for Chinook salmon because nearly all were age-0. We did not distinguish between spring- and fall-run salmon because size differences between these two runs are generally small (Fisher and Greene 1994), especially on the Feather River, where there is little segregation of spawn timing. Non-salmonid fishes were grouped into three categories: native cyprinids, centrarchids and tule perch *Hysterocarpus traski*. Native cyprinids included Sacramento pikeminnow *Ptychocheilus grandis* and hardhead *Mylopharadon conocephalus*. Centrachids included largemouth bass *Micropterus salmoides*, smallmouth bass *Micropterus dolomieui*, and various sunfishes. These groupings were necessary because definitive species identification was difficult. Furthermore, these categories combined species of similar behavior, life history, and management significance (Moyle 2002). Tule perch were separated because they were relatively common, easily identified and could not be logically grouped with other fish species. Non-salmonids were not categorized by size because most individuals were juveniles or older. Fish species other than those listed above were occasionally observed, but were not included in this analysis, see Seesholtz et al (2002) for consideration of other species.

Broad-scale snorkeling results were summarized as the number of fish observed per river mile in each survey year. It was not necessary to standardize these observations because sampling effort was equally applied throughout the 26 river kilometers. Intermediate- scale observations were standardized by number of fish observed per meter in each of the nine sampling reaches. Habitat use (cover, depth, velocity, etc.) was determined by calculating the percentage of all observations which occurred in a given habitat category. To assess size composition of the steelhead population, we assembled length frequency plots by month and seining site.

Stepwise binary logistic regression analysis (Legendre & Legendre 1998) was used to assess factors influencing the occurrence of steelhead and Chinook salmon. Fine scale survey results were analyzed at both the mesohabitat ($100m^2$) and microhabitat ($1m^2$) scale. Mesohabitat analysis was performed by treating the entire 25m reach as a sample. Reach habitat variables where steelhead or salmon were present (logistic response variable) were compared to reaches where fish were absent (logistic reference variable). Since intermediate scale surveys covered only nine reaches, it was not worthwhile to explore mesohabitat associations for these data. Microhabitat analysis was performed similarly (from both fine and intermediate scale surveys), except that individual $1m^2$ cells were considered rather than entire reaches. Reaches lacking salmon or steelhead observations were not included in the microhabitat analysis. This was necessary to prevent bias associated with inclusion of microhabitat availability data where no fish were present to select a microhabitat. Intermediate-scale microhabitat availability data were standardized by randomly selecting records from each reach relative to its size. Variables included for each scale of analysis are indicated in Table 5. Since this analysis was exploratory, rather than testing a priori hypotheses, we selected a relatively large critical (alpha) value of 0.1.

Results

Broad-scale snorkel survey

Distribution and abundance patterns for steelhead, Chinook salmon, native cyprinids, tule perch and non-native centrarchids (1999 – 2001) are summarized in Figures 2-7. In all years, nearly all age-0 steelhead observations occurred in the LFC. Within the LFC, age-0 steelhead distribution was strongly skewed upstream, with 91%, 77% and 84% of observations occurring in the first river mile in each successive survey year, respectively. Age-0 steelhead observations below the TAO accounted for 1% or less of all observations in each year (Figure 2). Abundance quickly decreased downstream of river mile 66, although abundance remained higher to mile 63 in 2001. A consistent cluster of observations is also evident upstream of the TAO (river mile 61 to 59). Like age-0, juvenile and adult steelhead were rare downstream of the TAO (<3% of total observations in all three years), but were much more broadly distributed in the LFC. Peaks in abundance occurred between river miles 66 and 63 and again in the area upstream of the TAO (Figure 3).

Age-0 Chinook salmon were the most abundant species observed in all three years (Figure 4). Nearly all observations (98%, 100% and 99%, respectively) were within the LFC. Although there was considerable interannual variation, young Chinook salmon were most common in the upper river miles and, in 2001, those just upstream of the TAO.

Cyprinid distribution and abundance varied greatly between years (Figure 5). Cyprinids were relatively common in the LFC, but, in contrast to steelhead and salmon, most were observed downstream of the TAO. Nearly all centrarchid observations were at the TAO or downstream (Figure 6). Centrarchids were particularly abundant in 2000. The majority of centrarchids observed were juveniles. Forty-two percent of *Lepomis spp.* and three percent of *Micropterus spp* were greater than 100 mm. Tule perch, a native freshwater embiotocid, were only observed in the HFC (Figure 7). Only in 2000 were they abundant.

Other species besides salmon, steelhead, cyprinids, centrarchids and tule perch were observed as part of broad scale snorkel surveys. Sacramento sucker *Catostomus occidentalis*, riffle sculpin *Cottus gulosus*, prickly sculpin *Cottus asper*, and carp *Cyprinus carpio* were very common in all parts of the survey area. However, these species were not enumerated because they were inefficiently sampled by snorkel survey methods. Species infrequently observed included wagasaki *Hypomesus nipponensis*, American shad *Alosa sapidissima*, and lamprey of the genus *Lamptera*. Seesholtz et al. (2002) contains more detailed information on these species in the Feather River.

Water temperatures recorded by electronic thermistors showed the expected seasonal and longitudinal trends (Figure 8). Temperatures were always coldest at the upstream end of the LFC and generally warmed from March through July. Monthly mean temperatures differed little between the downstream portion of the LFC and the HFC to Gridley Bridge, though there was some evidence of cooling downstream of the TAO in July and August.

Intermediate-scale snorkel survey

Intermediate scale surveys were generally consistent with the broad scale results (Figures 9-13). In all months, Hatchery Ditch (HD) showed the highest abundance of age-0 steelhead (Figure 9). Abundance in Auditorium Riffle (AuR) was also relatively high. April was the month of peak abundance for all sites, except Aleck Riffle (AlR). By

July, abundance was low in all survey reaches except HD. Age-0 steelhead were never observed at HFC survey reaches G95, Goose Riffle (GR) or Macfarland Riffle (MR).

Relative to age-0, age-1+ steelhead (>100mm) were more widely distributed in the LFC, but were observed commonly only later in the season (Figure 10). Age-1+ abundance was generally low, but was highest at the downstream portion of the LFC, particularly Robinson Riffle (RR) and Eye Riffle (ER). Chinook salmon were extremely abundant and broadly distributed in March and April surveys (Figure 11). In later months, salmon were no longer observed in HFC sites. Abundance after April dropped dramatically at all sites.

Cyprinids were rarely or never observed at the upper three sites, HD, Hatchery Riffle (HR), and AuR, but were somewhat common at other LFC reaches (Figure 12). At the three HFC sites G95, GR, and MR, peak abundance was in July and August. Centrarchids were not abundant at any site, but peak observations occurred at ER in July (Figure 13). Generally, centrarchids were more common at HFC sites. Tule perch were observed consistently at one LFC site, ER, and all three HFC sites (Figure 14). Tule perch abundance seemed to increase further downstream. Peak numbers occurred at MR in May.

Habitat Utilization

Both salmon and steelhead occurred most commonly in glide habitats and less commonly in slow-moving waters like pools and backwaters (Figure 15). Age-0 salmon and steelhead also used cover similarly, with small instream or overhead objects together being utilized in most observations (Figure 16). Less than twenty-five percent of steelhead and salmon observations were associated with no apparent cover type. Habitat use also appeared to be somewhat dependent on fish size. Age-0 steelhead became more common in riffle habitats and less common in pool and glides as fork length increased (Figure 17a). This trend was not as strong among juvenile Chinook salmon (Figure 17b). A shift to faster moving habitats and open waters is also reflected in other measures of age-0 steelhead microhabitat use. Focal point velocity, water depth and distance from bank all increased with fork length (Figure 18). Again, this trend was less clear among Chinook salmon, but velocity and depth did show a similar pattern of size dependence

(Figure 19). Cover use also varied with fish size. Small steelhead favored small woody debris and submerged aquatic vegetation, whereas more of the larger steelhead favored overhead objects or else occurred without in-stream cover (Figure 20). Age-0 Chinook salmon showed patterns of cover selection similar to age-0 steelhead, with larger fish observations increasingly void of in-stream cover and a more common association with overhead objects (Figure 21).

Habitat use varied substantially among non-salmonid fishes. Native cyprinds appeared to be extremely flexible in their selection of hydrogeomorphic units. Glides were used most commonly, but pools, riffles and backwaters were also common (Figure 22a). Centrarchids were largely observed in backwater habitats, but also more frequently than might be expected in riffles and glides (Figure 22b). The native tule perch were most strongly associated with glides, but occurred near equally among riffles, pools and backwaters (Figure 22c). Cover use among cyprinids was somewhat similar to that observed for salmonids. However, both absence of cover and use of large instream objects appeared relatively more common (Figure 23a). Centrarchids and tule perch, on the other hand, were rarely observed without some form of cover. Centrarchids most often used submerged aquatic vegetation (Figure 23b), while tule perch most often used small instream objects (Figure 23c). However, use of large instream objects (LIO) was also common, especially compared to salmon and steelhead.

Meso- and Microhabitat Preference

Logistic regression analysis of habitat preference among steelhead and salmon found that spatial scale and availability of habitat strongly affected the perceived importance of habitat variables. Mesoscale analysis for age-0 steelhead found only three variables significantly influencing fish presence or absence: river mile, large instream objects, and surface turbulence (Table 6). All three of these variables were positively associated with the occurrence of age-0 steelhead at the mesohabitat scale (25 m reaches). Surface turbulence was the weakest of these variables ($p=0.084$). Statistically non-significant variables are shown in Table 5. Microhabitat scale analysis based on intermediate scale snorkel surveys indicates five variables significantly affecting steelhead occurrence (Table 7). Water depth, current velocity, absence of overhead cover, absence of instream cover and gravel substrates were all found to be negatively associated with the occurrence of age-0 steelhead. In other words, 1 m^2 cells having higher values for these variables are less likely to contain steelhead. However, microhabitat analysis based on fine scale surveys indicates a smaller suite of important habitat variables: water depth, absence of overhead cover and distance from shore (Table 8). As with intermediate scale microhabitat selection, each of these variables is negatively associated with the occurrence of age-0 steelhead.

Habitat preference among age-1 and larger steelhead was also of interest, but insufficient data were available to perform these analyses from fine-scale snorkeling surveys. However, intermediate-scale snorkel surveys provided a sufficient sample size (n=201) to analyze microhabitat selection. Six microhabitat variables were found statistically significant: water velocity, absence of overhead cover, pool, absence of instream cover, sand substrate, and gravel substrate (Table 9). All of these variables except water velocity and absence of instream cover were negatively associated with occurrence of age-1 or larger steelhead.

River mile, average reach velocity, surface turbulence and small instream objects were significant predictors of age-0 Chinook salmon presence or absence (Table 10). River mile, surface turbulence, and small instream cover were all positively associated with the occurrence of Chinook salmon, while average reach velocity was negatively correlated. Intermediate scale microhabitat analysis indicated water depth, absence of overhead cover and gravel substrates were negatively correlated with the occurrence of age-0 Chinook salmon (Table 11). Only the pool hydrogeomorphic unit was positively associated with Chinook salmon. As with age-0 steelhead, fine scale snorkel survey microhabitat analysis identified a shorter list of significant variables: absence of overhead cover and presence of small instream objects (Table 12). Lack of overhead cover was negatively correlated while presence of small instream cover was positively associated with age-0 Chinook observations.

Steelhead mark recapture and size distribution

A total of 424 steelhead was captured and marked as part of seine sampling. A majority of these was captured in Hatchery Ditch (n=215), but fairly large numbers were also captured at Steep Riffle (n=111) and Matthews Riffle (n=71). Twenty-seven steelhead were captured at Bedrock Riffle. Recapture rates were low, with only 4.5% (19) of fish recaptured at the site where they were originally marked and released. Hatchery Ditch and Bedrock Riffle had the highest recovery rates, 6.9% (15) and 7.4% (2), respectively. Three fish were recaptured downstream from where they were originally tagged. No tagged fish were recaptured upstream of their tagging site. Fork lengths (FL) of captured fish differed considerably between seining sites (Figure 24). Average FL and FL standard deviation were successively larger at each site from upstream to downstream. Fish were smallest at Hatchery Ditch and largest at Steep Riffle. Steep Riffle also showed the greatest range in steelhead size. Monthly length frequency plots (based on snorkel surveys) indicates that steelhead size composition also changed seasonally. Recently emerged age-0 steelhead were observed early in the season beginning in March (Figure 25). As expected, this year class of steelhead grew as the season progressed. However, in later months many larger steelhead (>100 mm) began to be observed.

Discussion

The distribution and abundance of fishes in the lower Feather River appears to be strongly structured by environmental conditions operating at large spatial scales. Results from all three types of snorkel surveys suggest that river mile, and by implication, its correlates (water temperature, HFC or LFC, proximity to the FBD), explained much of the observed variation in fish distribution. The Thermalito Afterbay Outlet causes a rapid transition in physical conditions that is mirrored clearly in the types and numbers of fish encountered both upstream (in the LFC) and downstream (in the HFC). Salmonids, particularly juvenile steelhead, were always more abundant in the LFC, while cyprinids, centrarchids and tule perch were always more abundant in the HFC. The existence of two distinct fish assemblages is consistent with the findings from seining and rotary screw trap sampling reported in Seesholtz et al (2002).

The scale at which organisms respond to available habitats is an important ecological issue (Wiens 1989, Poizat and Pont 1996), and strongly affects perceived distribution patterns and the importance of habitat variables. In our studies, all fish species showed an association with certain microhabitat characteristics. For example, centrarchids were most often found in backwaters near submerged aquatic vegetation. age-0 steelhead selected shallow, relatively slow moving waters with overhead and in-channel cover. However, these microhabitat types are common in the lower Feather River. That is, vegetated backwaters and shallow, shoreline glides are not unique to the river reaches where these species consistently occurred. Thus, the selection of small-scale habitat (i.e. microhabitat) appears to be strongly constrained by large-scale physical conditions such as river mile and water temperature.

The relative importance of various microhabitat variables changed substantially, depending on the scale at which availability was measured. Analysis from intermediate-scale snorkel surveys was based upon a 200 to 600 meter reach, which included at least one pool-riffle sequence, both river banks and everything in between. Fine-scale snorkel surveys were focussed on areas thought to meet the minimum habitat criteria for Age-0 steelhead. Fine-scale reaches were selected among riffle-glides, based upon a much shorter reach (25 m), oriented along one bank and extended out only 4 meters. Because it treated a broad area as available habitat, the intermediate-scale microhabitat analysis identified many more variables as significantly affecting occurrence of age-0 steelhead than did the fine-scale analysis. This result implies that age-0 steelhead were highly specific in their microhabitat needs, because much of the area in the intermediate-scale analysis represented habitats that steelhead almost never used.

Proximity to river's edge may be the strongest determinant of whether age-0 steelhead used a given microhabitat cell. Steelhead less than 80 mm were almost always observed within 2 meters of shore (Figure 18). When this affinity for shoreline areas was taken into consideration (i.e., in the fine-scale analysis), only depth, overhead cover and distance from shore had statistically significant effects on microhabitat distribution. Similar results are apparent in comparing intermediate and fine scale based microhabitat selection among age-0 Chinook salmon.

The collective results of our multi-scale distribution analysis demonstrate some specificity in microhabitats among age-0 steelhead and Chinook salmon. When viewed in isolation, these microhabitat requirements seemed amply available in the lower Feather

River. However, when small-scale habitats were matched within large-scale requirements, the overall amount of suitable habitat shrank.

As an example, the scarcity of riffle/glide habitats in the lower Feather River constrains the amount of suitable smaller scale habitats. Glides were used by age-0 salmonids much more than pools or backwaters in intermediate-scale surveys (Figures 15 and 17). Similarly, pools and slow-moving waters were generally devoid of rearing salmonids in broad-scale surveys. This difference is striking because riffle/glide habitats are rare on the Feather River, being interspersed with much larger sections of slow moving, sometimes deep, pool habitats. However, hydrogeomorphic habitat selection was poorly represented in the statistical analyses, because most sampling was in riffle/glide areas thought to be potential salmonid rearing habitat.

The fact that large scale conditions appear to drive observed distribution and abundance patterns for lower Feather River fishes has important implications for the study and management of the river. Physical habitat simulation models (e.g. PHABSIM) are a common approach to studying instream flow needs in regulated rivers. These models are typically used with the assumption that fish habitat needs may be characterized by simple microhabitat variables such as depth, substrate, velocity and cover. However, our results suggest that focussing on small-scale habitat use and ignoring broad scale conditions would provide an inaccurate view of habitat suitability under different flow regimes. Thus, management actions emphasizing the effects of flow on simple microhabitat availability are unlikely to improve the productivity and success of wild salmonids in the lower Feather River.

We expected the presence of side channels, like Hatchery Ditch and those found near Steep and Eye Riffles, to be a strong predictor of steelhead abundance. Side channels often meet many of the micro- and meso-scale habitat requirements that we have described, including overhead cover. Although riparian canopy percentage was measured for only 67 of 136 reaches in 2001 (not enough to include as a variable in the statistical analysis), it had a fairly strong positive relationship with age-0 steelhead abundance (p=0.089) in a preliminary logistic regression analysis. Broad and intermediate-scale surveys indicated that side channels (seemingly those with good canopy cover) were even more important to age-1+ steelhead. Unfortunately, inadequate sample size made it impossible to explore these relationships in the meso-habitat statistical analysis. Canopy cover was better sampled in 2002 snorkel surveys, so its importance relative to side channels as a reach scale habitat variable will be better understood in subsequent analyses.

Preliminary work in the Feather River indicated that age-0 steelhead were restricted to the upstream reaches of the Low Flow Channel (LFC). At the outset of our study, this restriction was attributed to any of several factors: selection of cold water, predator avoidance, and habitat preference. Our snorkeling studies confirm that the bulk of age-0 steelhead occur at the upstream end of the LFC. However, neither water temperature, predation pressure nor habitat availability convincingly explain this pattern.

Water temperatures within the entire LFC are typically well within the thermal preference and tolerance range of steelhead (Myrick and Cech 2000). Furthermore, age-1 and larger steelhead were typically more abundant at the downstream end of the LFC where water temperatures usually are higher in summer. Nor does size-dependent temperature selection provide a cogent explanation, since younger fish typically select warmer water than older fishes of the same species. We found little evidence of any effect of predation on the distribution of juvenile steelhead within the LFC. The most likely predators, Sacramento pikeminnow and Micropterus spp. basses, were rare throughout the LFC. Also, changes in seasonal distribution of age-0 steelhead were not consistent with an expected response to predation pressure. Recently emerged age-0 steelhead were restricted to the upstream end of the LFC from when surveys began in March. If this distribution were driven by predation pressure, we would expect to see a broad distribution early in the season that became more restricted as the season progressed. Predation may be a more significant factor for salmonids living in the HFC where predatory fishes were more common and where water temperatures were generally warmer.

Suitable microhabitat features (current velocities, depth, and cover) were not restricted to the upstream end of the LFC. Side channels, with abundant instream and overhead cover, were available at Hatchery Ditch, other locations in the LFC (Eye Riffle, Steep Riffle) and even some locations in the HFC. Although age-0 steelhead densities were highest in Hatchery Ditch, overall abundance was generally high throughout the upper river mile of the LFC. In light of these facts, the availability of rearing habitat at the upstream end of the LFC does not seem to convincingly explain the observed distribution pattern.

Proximity to the Fish Barrier Dam (upstream migratory limit) and to the Feather River Fish Hatchery may provide a more complete explanation. Central Valley steelhead historically spawned as far upstream as they could physically reach (Yoshiyama et al. 1996). In a dammed river where the bulk of the historic migratory range is cut off, steelhead would be expected to swim up to the first artificial barrier before spawning. Our Feather River data from the period when steelhead fry emerge (March-April) suggest that spawning is largely restricted to the upper mile of the LFC (Figure 9). Similarly, informal bank and snorkel surveys found steelhead spawning only in the upper reaches of the LFC (DWR unpublished). Age-0 steelhead surveys on the Yuba River (Kozlowski unpublished) and redd surveys on the American River (Hannon and Healey 2002) have also found highest densities at upstream sampling sites.

The Feather River Fish Hatchery, at the upstream end of the LFC, may exert a powerful influence on the spawning distribution of steelhead. Chemical or olfactory cues in effluent from the Hatchery may have a strong attraction for fish of hatchery origin. Hatchery Ditch, where much of the steelhead spawning occurs, is fed entirely by effluent from the hatchery settling pond. Mackey et al. (2001) found that hatchery steelhead in an Oregon river tended stay close to the hatchery, apparently as a result of chemical imprinting on the hatchery's water supply. It is possible that hatchery steelhead are spawning at the upstream end of the LFC for its proximity to the hatchery, rather that its overall habitat suitability.

On the lower Feather River, newly hatched steelhead were largely restricted to the upstream end of the LFC, but gradually dispersed downstream. Other studies have also found higher upstream densities of rearing steelhead (e.g. Roper et al. 1994). In these studies, unsuitably high water temperature in the lower reaches may have caused greater proportions of young steelhead to emigrate (Roper et al. 1994) or decreased their survival (Bisson and Davis 1976), resulting in lower observed steelhead densities. Juvenile steelhead typically move downstream in search suitable habitat and adequate food supplies (Peven et al. 1994). Roper et al. (1994) also found that age-1 and older steelhead were most abundant in middle reaches, while age-0 dominated areas further upstream.

Our studies indicated a substantial downstream migration of age-0 steelhead. Those fish averaged larger than fish living upstream (Figure 24), and age-1+ fish were generally more common, relative to age-0 fish, in middle and downstream reaches of the LFC (Figures 2 and 3). The catch in rotary screw traps indicates that many age-0 steelhead emigrate from the LFC shortly after emergence (Seesholtz et al 2002). The fate of these fish is unknown, but steelhead typically reside in-river for at least one year prior to smolting (McEwan 1999). Most of the apparent emigrants from the LFC are quite small, and therefore should be physiologically incapable of smoltification.

Our surveys found numerous age-0 steelhead early in the season, but far fewer as the season progressed (Figure 9, Figure 25). Fish remaining in the river appear to grow slowly; mean fork length of age-0 steelhead in August was about 70mm. Juvenile steelhead older than age-0 were scarce in our surveys, which suggests that few survive or remain in the lower Feather River into their second year. The Yuba River and Sacramento River (below Keswick Dam) support year-round populations of adult resident rainbow trout and/or steelhead. We saw little evidence for a similarly strong population in the Feather River. However, we detected an influx of 100 to 300 mm-long steelhead, more typical of pre-smolt juveniles, from June to August. These fish may primarily reside downstream of the TAO, where food and habitat are more abundant (Esteban 2002). In summer they may migrate into the LFC in search of cooler water. Many of the age-0 steelhead which emigrate from the LFC may also adopt this strategy. Our surveys could easily miss these individuals, given the river size below TAO, resulting low fish densities, poor visibility and greater observer avoidance among older steelhead.

Age-0 Chinook salmon were very abundant early in the season, but appeared to begin their downstream migration early, and were nearly absent from our surveys in summer (Figure 11). This observation is consistent with an ocean type life history and with the emigration pattern described by our rotary screw trap sampling (Seesholtz et al. 2002). A few age-0 salmon remained in the LFC through each summer of our survey.

However, these individuals probably reflect normal behavioral variation rather than a distinct life history akin to some Chinook salmon races (e.g. spring-run).

Refrences

Bayley, P. B. and H. W. Li (1992). Riverine fishes. The rivers handbook: hydrological and ecological principles. P. Calow and G. E. Petts (editors). Oxford, Blackwell: 251-281.

Bisson, P. A. and G. E. Davis (1976). "Production of juvenile chinook salmon, Oncorhynchus tshawytscha, in a heated model stream." U.S. National Marine Fisheries Service Fishery Bulletin **74**: 763-774.

Brown, L. R. (2000). "Fish communities and their association with environmental variables, lower San Joaquin River drainage, California." Environmental Biology of Fishes **57**: 251-269.

Brown, L. R. and T. Ford (2002). "Effects of flow on the fish communities of a regulated California river: implications for managing native fishes." River Research and Applications **18**: 331-342.

Esteban, E. M. (2002). Salmonid prey selection: Evaluating a food availability model in Northern California with young-of-the-year Chinook salmon (Onchorynchus tshawytscha) and Steelhead trout (Onchorynchus mykiss). Department of Biology. Chico, California State University Chico: 43.

Fausch, K. D., C. E. Torgersen, et al. (2002). "Landscape to riverscapes: bridging the gap between research and conservation of stream fishes." Bioscience **52**(6).

Hannon, J. and M. Healey (2002). American River Steelhead Redd Surveys, 2001-2002. Sacramento, California Department of Fish and Game. 19 pages

Kozlowski, J. (2000). Summary of fish collections for lower Yuba River steelhead/rainbow trout surveys, Summer 1999. University of California Davis.

Legendre, P. and L. Legendre (1998). Numerical Ecology. Amsterdam, Elsevier Science. 853 pages.

Ligon, F. K., W. E. Dietrich, et al. (1995). "Downstream ecological effects of dams: a geomorphic perspective." Bioscience **45**: 183-192.

Mackey, G., J. E. McLean, et al. (2001). "Comparisons of run timing, spatial distribution, and length of wild and newly established hatchery populations of steelhead in Forks Creek, Washington." North American Journal of Fisheries Management **21**: 717-724.

McEwan, D. R. (2001). Central Valley Steelhead. Contributions to the biology of Central Valley salmonids. R. L. Brown (editor). Sacramento, California Department of Fish and Game. **1:** 1-44.

Mount, J. F. (1995). California Rivers and Streams: the conflict between fluvial process and land use. Berkeley, University of California Press.

Moyle, P. B. (2002). Inland Fishes of California. Berkeley, California. University of California Press.

Myrick, C. and J. J. Cech (2000). Growth and thermal biology of Feather River steelhead under constant and cyclical temperatures. Davis, University of California, Department of Wildlife, Fish and Conservation Biology.

Peven, C. M., R. R. Whitney, et al. (1994). "Age and length of steelhead smolts from the Mid-Columbia River Basin, Washington." North American Journal of Fisheries Management **14**: 77-86.

Poizat, G. and D. Pont (1996). "Multi-scale approach to species-habitat relationships: juvenile fish in a large river section." Freshwater Biology **36:** 611-622.

Roper, B. B., D. L. Scarnecchia, et al. (1994). "Summer distribution of and habitat use by chinook salmon and steelhead within a major basin of the south Umpqua River, Oregon." Transactions of the American Fisheries Society **123**: 298-308.

Schlosser, I. J. (1991). "Stream fish ecology: A landscape perspective." BioScience **41**: 704-712.

Schlosser, I. J. (1995). "Critical landscape attributes that influence fish population dynamics in headwater streams." Hydrobiologia **303**: 71-81.

Seesholtz, A., B. Cavallo, et al. "Lower Feather River Juvenile Fish Communities: Distribution, Emigration Patterns, and Association with Environmental Variables." Accepted, American Fisheries Society Early Life History Symposium.

Shapovalov, L. and A. C. Taft (1954). The life histories of the steelhead rainbow trout (Salmo gairdneri gairdneri) and silver salmon (Oncorhynchus kisutch). Sacramento, California Department of Fish and Game.

Ward, J. V. and J. A. Stanford (1983). The serial discontinuity concept of lotic ecosystems. Dynamics of lotic ecosystems. T. D. Fontaine and S. M. Bartell (editors). Ann Arbor, Ann Arbor Science: 29-42.

Wiens, J. A. (1989). "Spatial scaling in ecology." Functional Ecology **3**: 385-397.

Yoshiyama, R. M., E. R. Gerstung, et al. (1996). Historical and present distribution of chinook salmon in the Central Valley drainage of California. Sierra Nevada Ecosystem Project: Final report to Congress. **III:** 309-362.

Table 1. Substrate classification system.

Code	Substrate Description
1	Fines – Small Gravel (0-50 mm) (0 – 2 in)
2	Small – Medium Gravel (50 – 150 mm) (2 – 6 in)
3	Medium – Large Cobble (150 – 300 mm) (6 – 12 in)
4	Boulder (> 300 mm) (> 12 in)

Table 2 . Cover classification system.

Code	Cover description
None	No apparent cover
SIO	Small – Medium instream objects/woody debris (< 31 cm or 1 ft. diameter)
LIO	Large instream objects/woody debris (> 31 cm or 1 ft. diameter)
OvOb	Overhead objects
SAV	Submerged aquatic vegetation
UB	Undercut bank

Table 3 . Hydrogeomorphic classification system.

Code	Hydrology Description
R	Riffle
G	Glide
P	Pool
W	Backwater

Table 4. Stream characteristics for each Intermediate-scale snorkel site. All stream measurements were completed in 1999. NA represents No Apparent cover, SWD represents Small Wood Debris/Objects, LWD represents Large Woody Debris/Objects, OvOb represents Overhead Objects, SAV represents Submerged Aquatic Vegetation, and UnBa represents Undercut Bank.

	Intermediate-scale snorkel sites								
Measurement	HD	HR	AR	AR	RR	ER	G95	GR	MR
River mile	66.5	66.6	66.5	63.5	61.5	60.2	57.3	54.8	52.3
Linear distance (m)	330	250	230	200	665	409	227	595	274
	Habitat characteritics by site								
Hydrogeomorphic unit (%)									
Riffle	40	20	13	27	26	4	34	10	0
Glide	42	80	79	25	60	72	61	31	94
Pool	18	0	8	48	14	24	5	59	6
Cover (%)									
NA	32	87	73	94	87	40	90	84	69
SWD	15	3	9	0	3	20	2	3	7
LWD	0	1	0	2	0	1	1	0	7
OvOb	51	7	17	3	8	23	3	13	14
SAV	1	0	0	2	3	15	3	0	4
UnBa	1	2	0	0	0	0	0	0	0
Velocity percentile (ft/s)									
25th	0.50	0.50	0.85	0.00	0.50	0.50	0.62	0.51	0.50
50th	1.09	1.00	1.80	0.50	1.22	1.18	2.20	1.95	1.94
75th	1.92	3.30	2.60	1.98	2.85	1.90	3.26	3.01	4.24
100th	3.77	12.50	4.39	3.57	11.70	4.23	6.54	6.54	7.73
Depth percentile (m)									
25th	0.18	0.40	0.49	0.35	0.42	0.32	0.39	0.64	0.52
50th	0.24	0.65	0.70	0.55	0.55	0.55	0.58	1.65	0.90
75th	0.30	1.00	0.90	0.77	0.85	0.75	0.79	2.50	1.50
100th	0.63	1.50	1.50	1.30	1.50	1.80	1.50	3.00	2.90

Table 5. Description of variables evaluated for binary logistic regression analysis of habitat use among salmon and steelhead

Logistic Regression Variables	Variable Description	Fine Scale Mesohabiat	Fine Scale Microhabitat	Intermediate Scale Microhabitat
Depth			x	x
Velocity			x	x
OCOVA	Overhead Cover Absent	x	x	1
ICOVA	Instream Cover Absent	x	x	2
ICOVB	Small Instream Cover	x	x	
ICOVC	Large Instream Cover	x	x	
SURFTURB	Surface Turbulence	x	x	
SUBGRAV	Gravel Substrate		x	3
SUBSAND	Sand Substrate		x	3
DISTANCE	Distance from shore		x	
Pool				4
AVGVEL	Average Reach Velocity	x		
AVGDEPTH	Average Reach Depth	x		
Rivermile		x		
SideChannel		x		

1: relative to all types of overhead cover
2: relative to all types of instream cover
3: relative to cobble and larger substrates
4: relative to riffles and glides

Table 6. Binary logistic regression results for analysis of mesohabitat selection among age-0 sized steelhead. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	102		
	1 (response)	34		
Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
Constant	-16.162	5.087	-3.177	0.001
Rivermile	0.273	0.071	3.827	0.000
ICOVC	1.209	0.395	3.063	0.002
SURFTURB	0.08	0.046	1.728	0.084

Table 7. Binary logistic regression results for analysis of microhabitat selection among age-0 sized steelhead. Data from intermediate scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	510		
	1 (response)	802		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	5.890	0.390	15.087	0.000
Depth	-6.688	0.484	-13.812	0.000
Velocity	-0.167	0.084	-1.999	0.046
OCOVA*	-1.981	0.255	-7.764	0.000
ICOVA**	-0.806	0.223	-3.620	0.000
SUBGRAV***	-1.005	0.227	-4.437	0.000

*relative to any type of overhead cover
**relative to all types of instream cover
***relative to cobble and larger substrates

Table 8. Binary logistic regression results for analysis of microhabitat selection among age-0 sized steelhead. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	1210		
	1 (response)	157		
Parameter	**Estimate**	**S.E.**	**t-ratio**	**p-value**
Depth	-0.032	0.008	-4.204	0.000
OCOVA	-0.007	0.003	-2.189	0.029
DISTANCE	-0.226	0.115	-1.957	0.05

Table 9. Binary logistic regression results for analysis of microhabitat selection among age-1 sized steelhead. Data from intermediate scale snorkel surveys. Only variables with p-value <0.1 reported. Insufficient data was available to conduct similar analysis from fine scale surveys.

Category Choice	0 (reference)		510		
	1 (response)		201		
Parameter	Estimate		S.E.	t-ratio	p-value
Constant		1.571	0.410	3.836	0.000
Velocity		0.162	0.074	2.197	0.028
OCOVA*		-3.520	0.457	-7.696	0.000
Pool**		-1.509	0.434	-3.476	0.001
ICOVA***		1.397	0.467	2.989	0.003
SUBSAND****		-0.776	0.286	-2.714	0.007
SUBGRAV****		-1.154	0.219	-5.258	0.000

*relative to any type of overhead cover
**relative to riffles and glides
***relative to all types of instream cover
****relative to cobble and larger substrates

Table 10. Binary logistic regression results for analysis of mesohabitat selection among juvenile Chinook salmon. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	91		
	1 (response)	45		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	-12.521	4.354	-2.876	0.004
Rivermile	0.12	0.048	2.505	0.012
AVGVEL	-1.091	0.541	-2.017	0.044
SURFTURB	0.173	0.056	3.074	0.002
ICOVB	0.193	0.076	2.529	0.011

Table 11. Binary logistic regression results for analysis of microhabitat selection among juvenile Chinook salmon. Data from intermediate scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	510		
	1 (response)	169		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	2.660	0.441	6.032	0.000
Depth	-3.270	0.498	-6.562	0.000
OCOVA*	-2.132	0.312	-6.825	0.000
Pool**	0.981	0.295	3.321	0.001
SUBGRAV***	-0.548	0.290	-1.889	0.059

*relative to all types of overhead cover
**relative to riffles and glides
***relative to cobble and larger substrates

Table 12. Binary logistic regression results for analysis of microhabitat selection among juvenile Chinook salmon. Data from fine scale snorkel surveys. Only variables with p-value <0.1 reported.

Category Choice	0 (reference)	1618		
	1 (response)	190		
Parameter	Estimate	S.E.	t-ratio	p-value
Constant	-2.663	0.753	-3.538	0.000
OCOVA	-0.009	0.006	2.153	0.000
ICOVB	0.031	0.003	-3.566	0.031

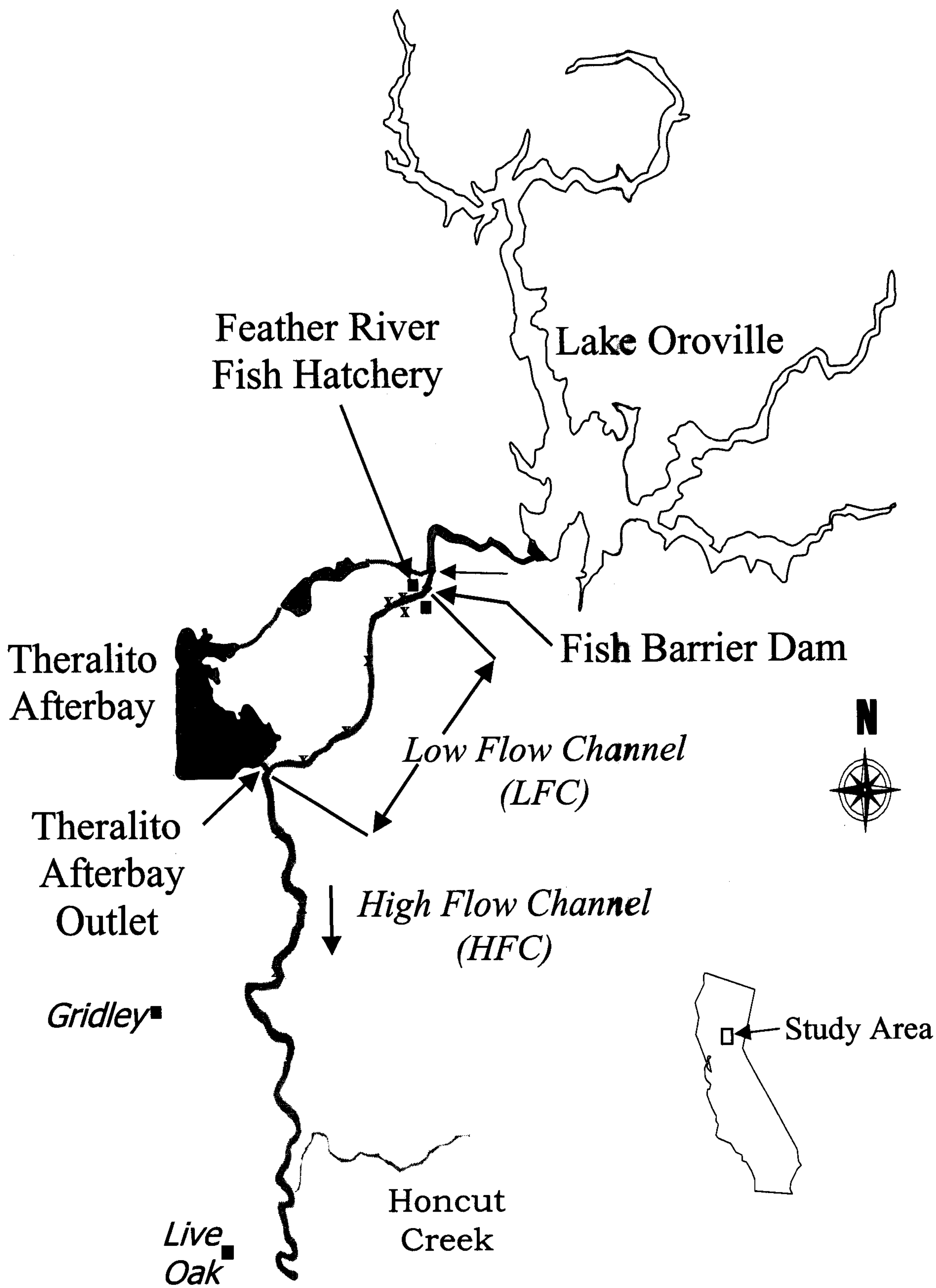

Figure 1. Feather River study area. The approximate locations of intermediate scale snorkeling sites are indicated by an "x".

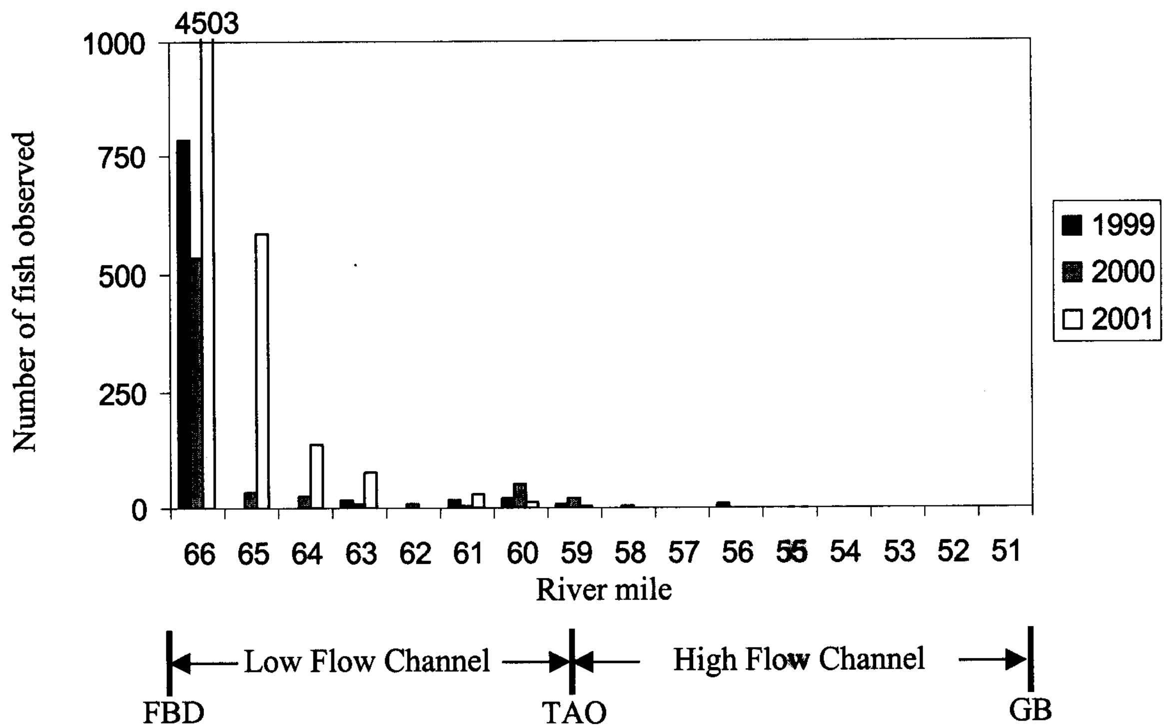

Figure 2. Number of age-0 steelhead observed during 1999, 2000 and 2001 broad scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

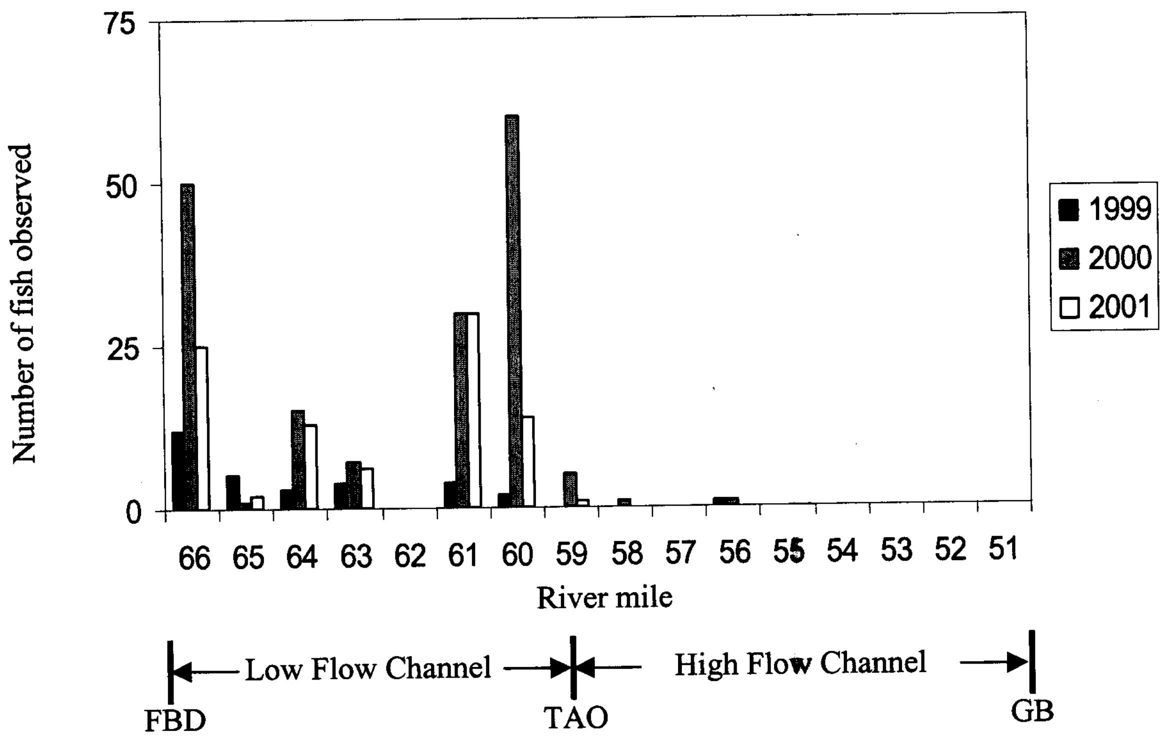

Figure 3. Number of juvenile and adult (age-1+) steelhead observed during 1999, 2000 and 2001 broad scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

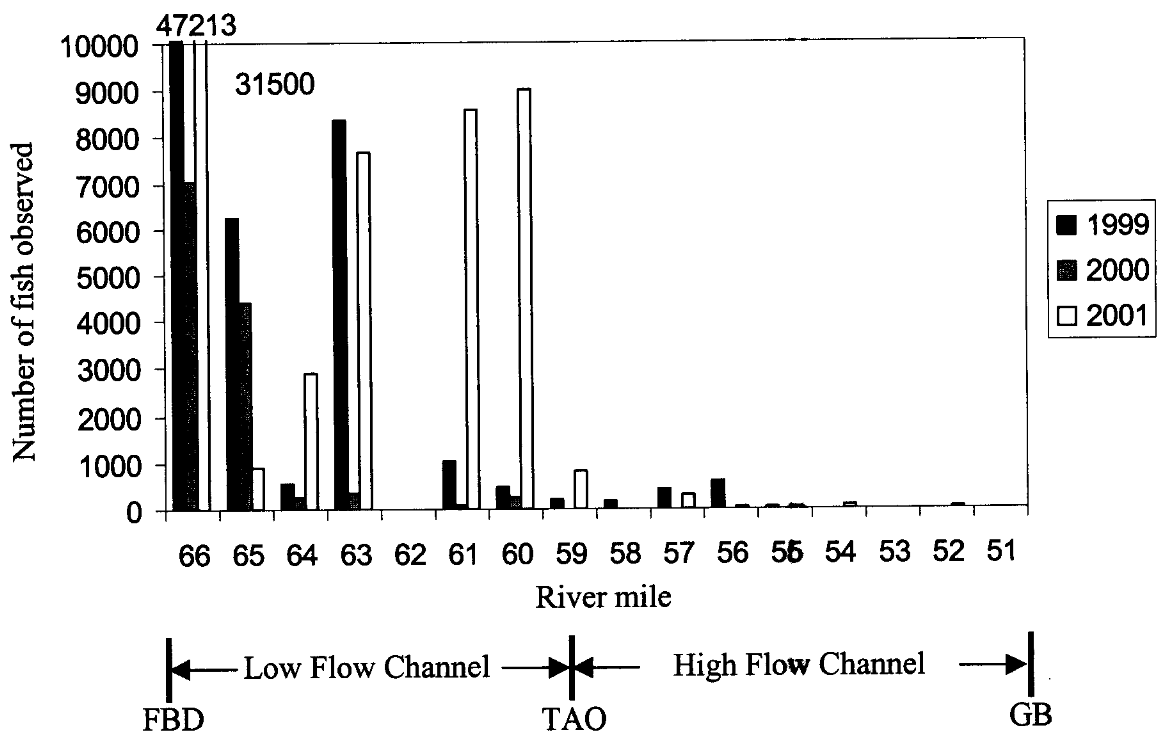

Figure 4. Number of age-0 Chinook salmon observed during 1999, 2000 and 2001 broad scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

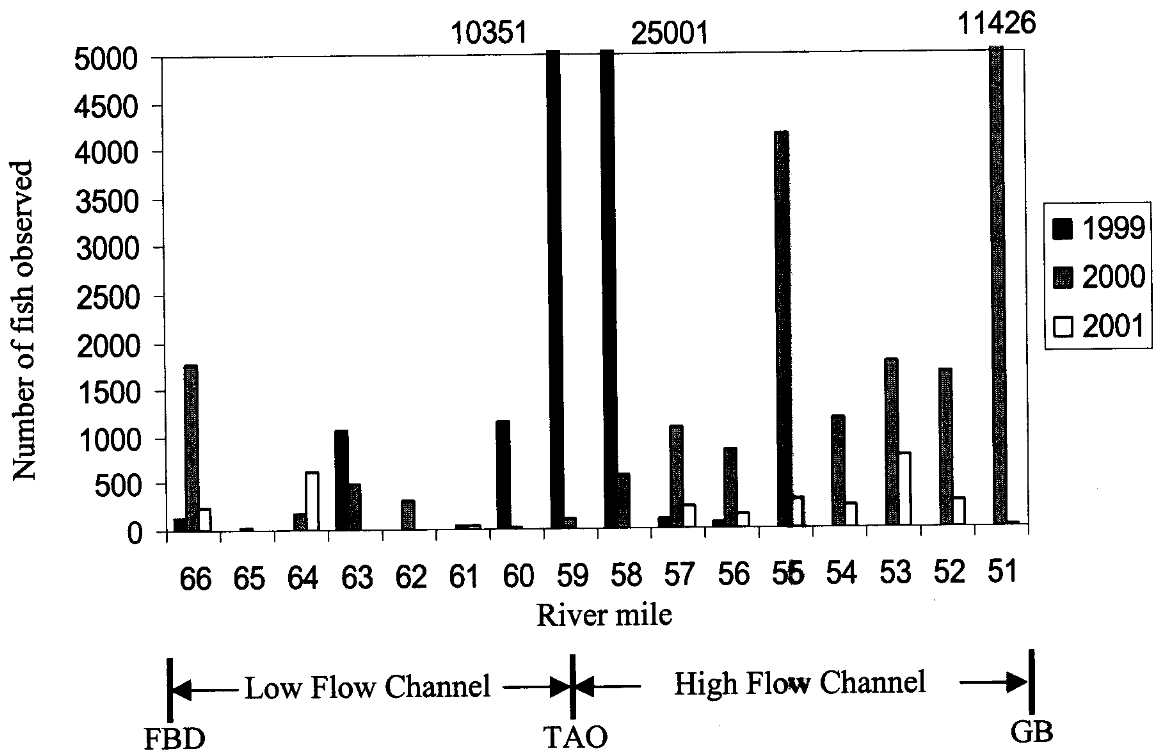

Figure 5. Number of native cyprinids observed during 1999, 2000 and 2001 broad scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

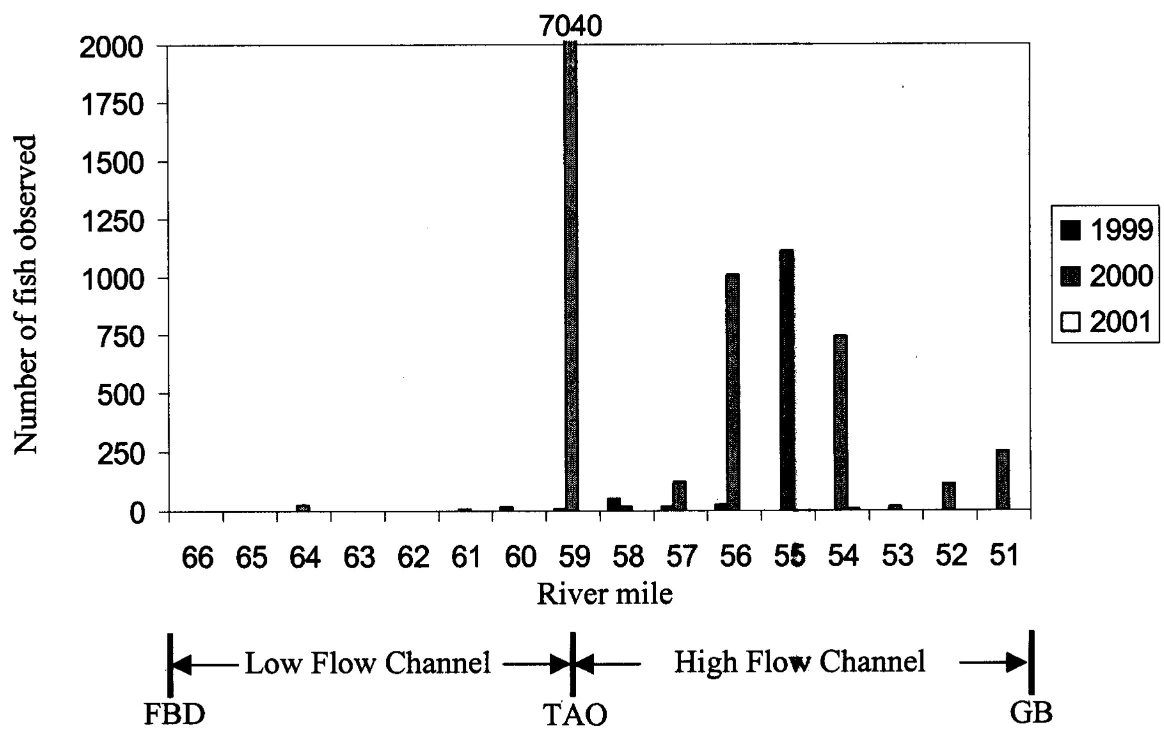

Figure 6. Number of centrarchids observed during 1999, 2000 and 2001 broad scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

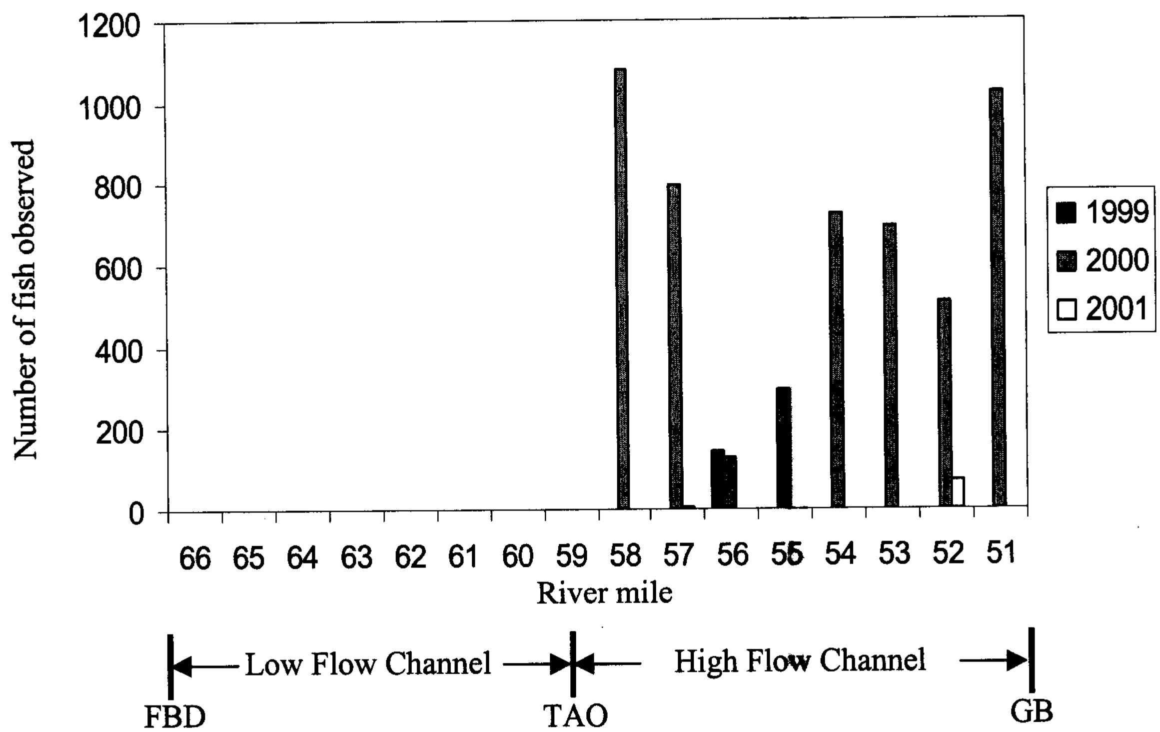

Figure 7. Number of tule perch observed during 1999, 2000 and 2001 broad scale snorkel surveys. The Fish Barrier Dam (FBD), Thermalito-Afterbay Outlet (TAO), Gridley Bridge (GB), as well as the Low Flow Channel and High Flow Channel, are indicated under the appropriate river mile.

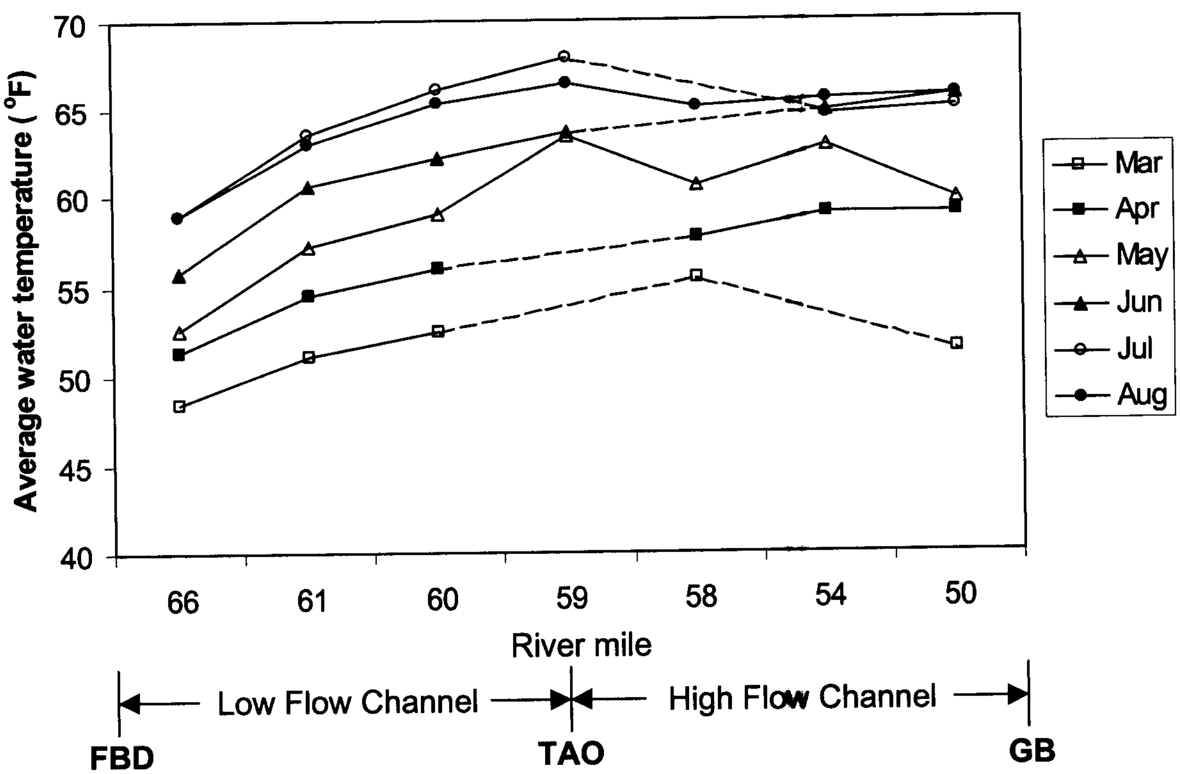

Figure 8. Average monthly temperature (°F) from continuous data loggers positioned throughout the lower Feather River (2001). Dashed lines represent missing data.

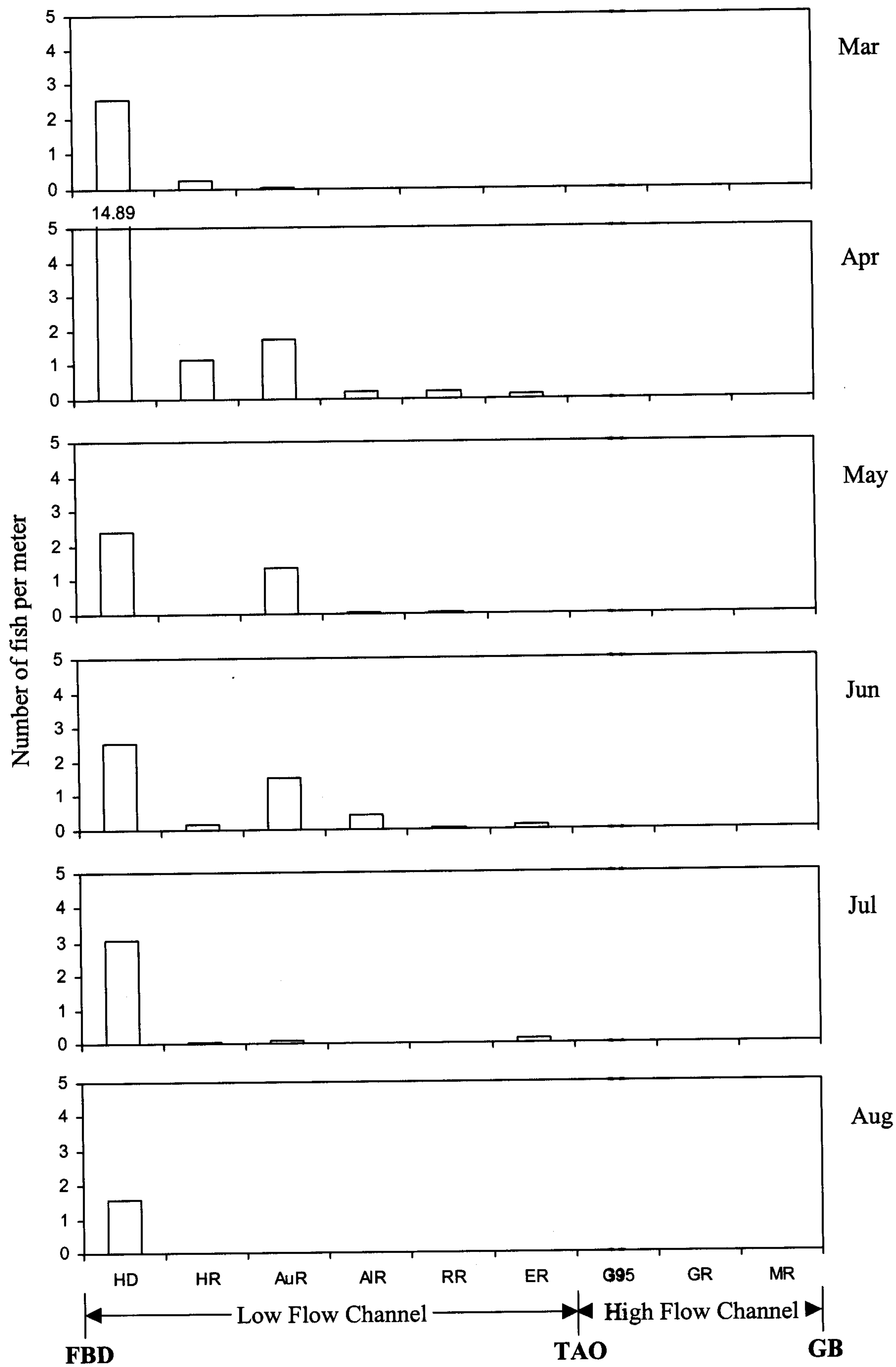

Figure 9. Seasonal abundance of age-0 steelhead at nine intermediate scale snorkeling sites. Abundance is reported as the number of fish observed per linear meter of river bank.

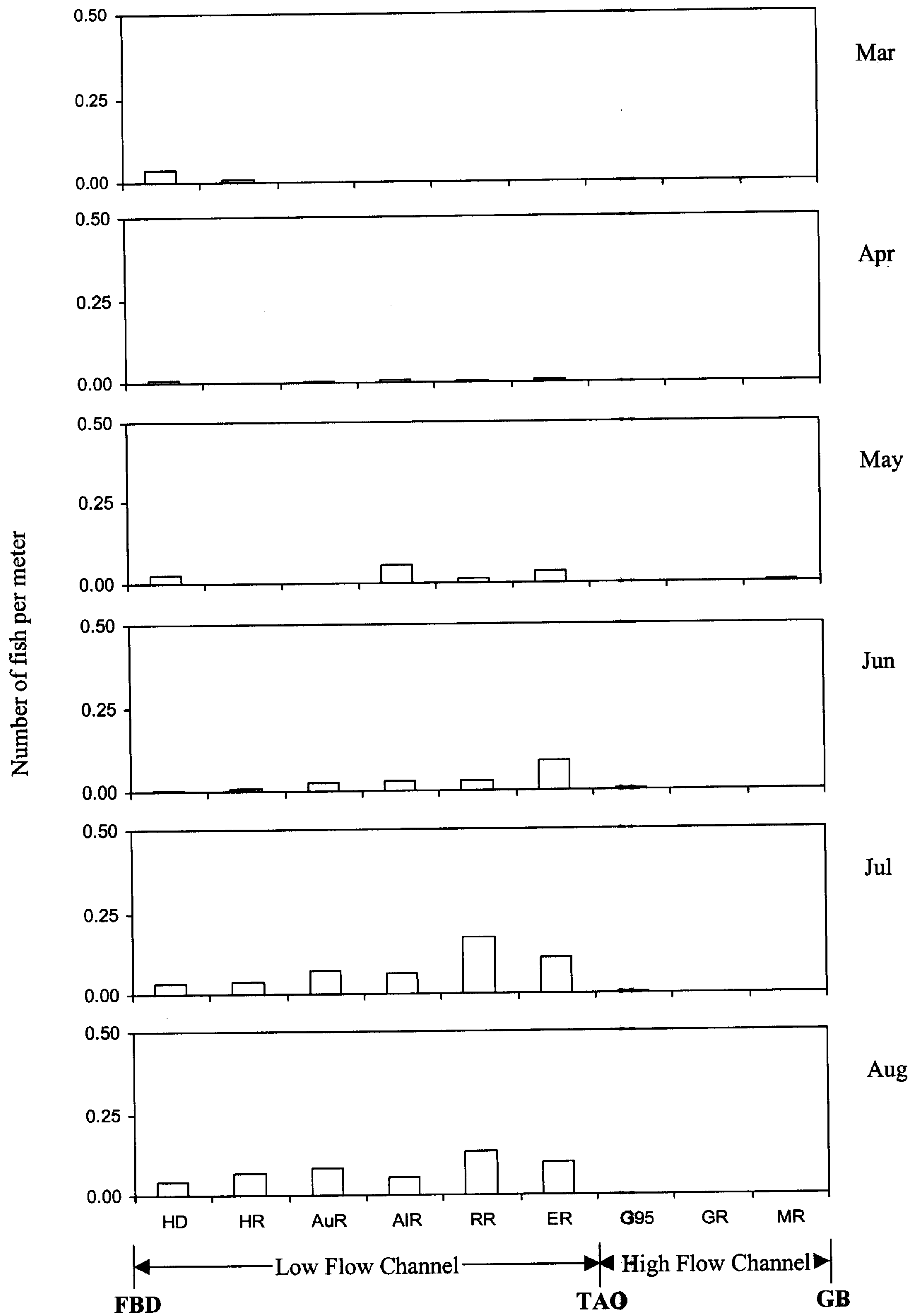

Figure 10 . Seasonal abundance of age-1+ steelhead at nine intermediate scale sites. Abundance is reported as the number of fish observed per linear meter of river bank.

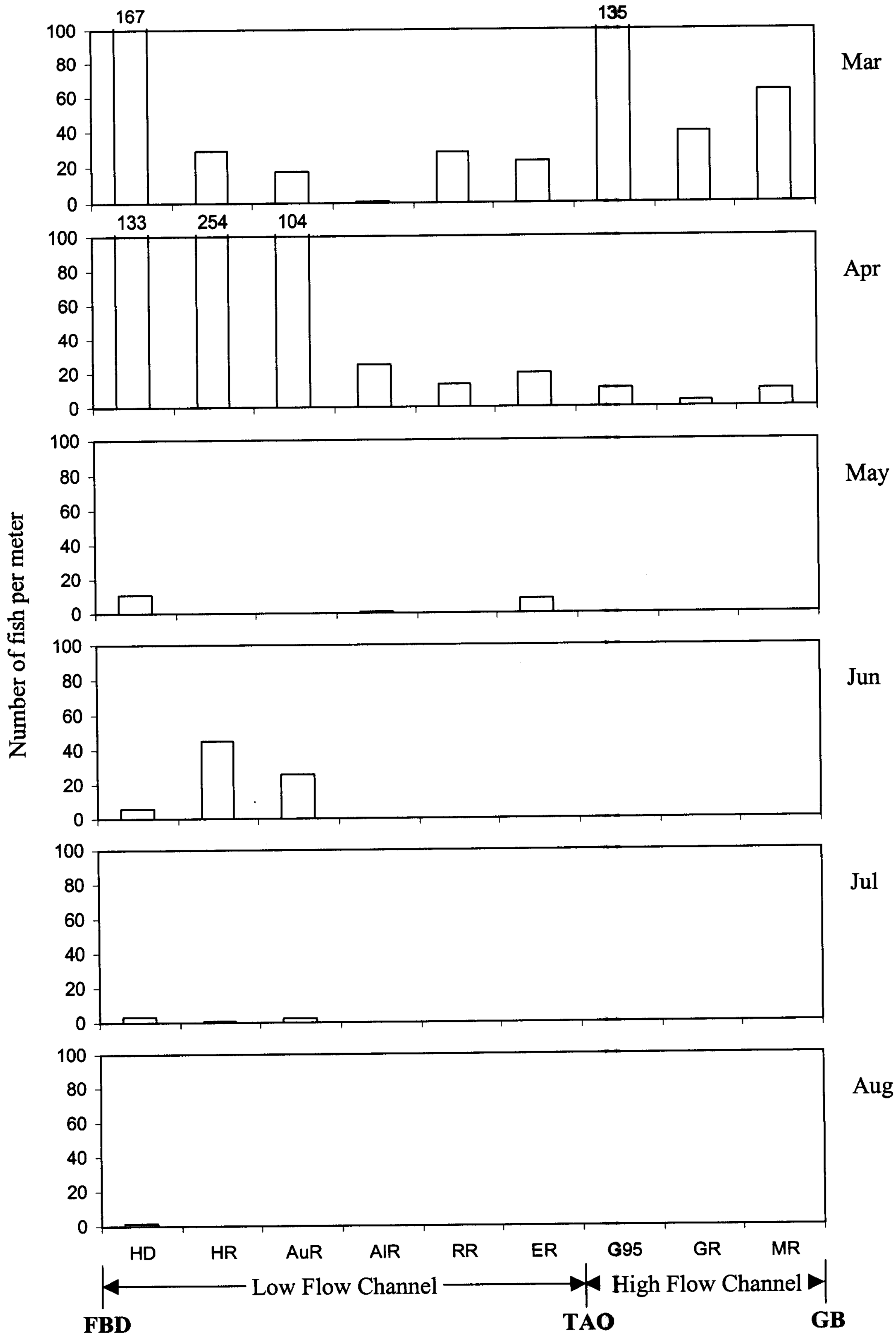

Figure 11. Seasonal abundance of age-0 Chinook salmon at nine intermediate scale sites. Abundance is reported as the number of fish observed per linear meter of river bank.

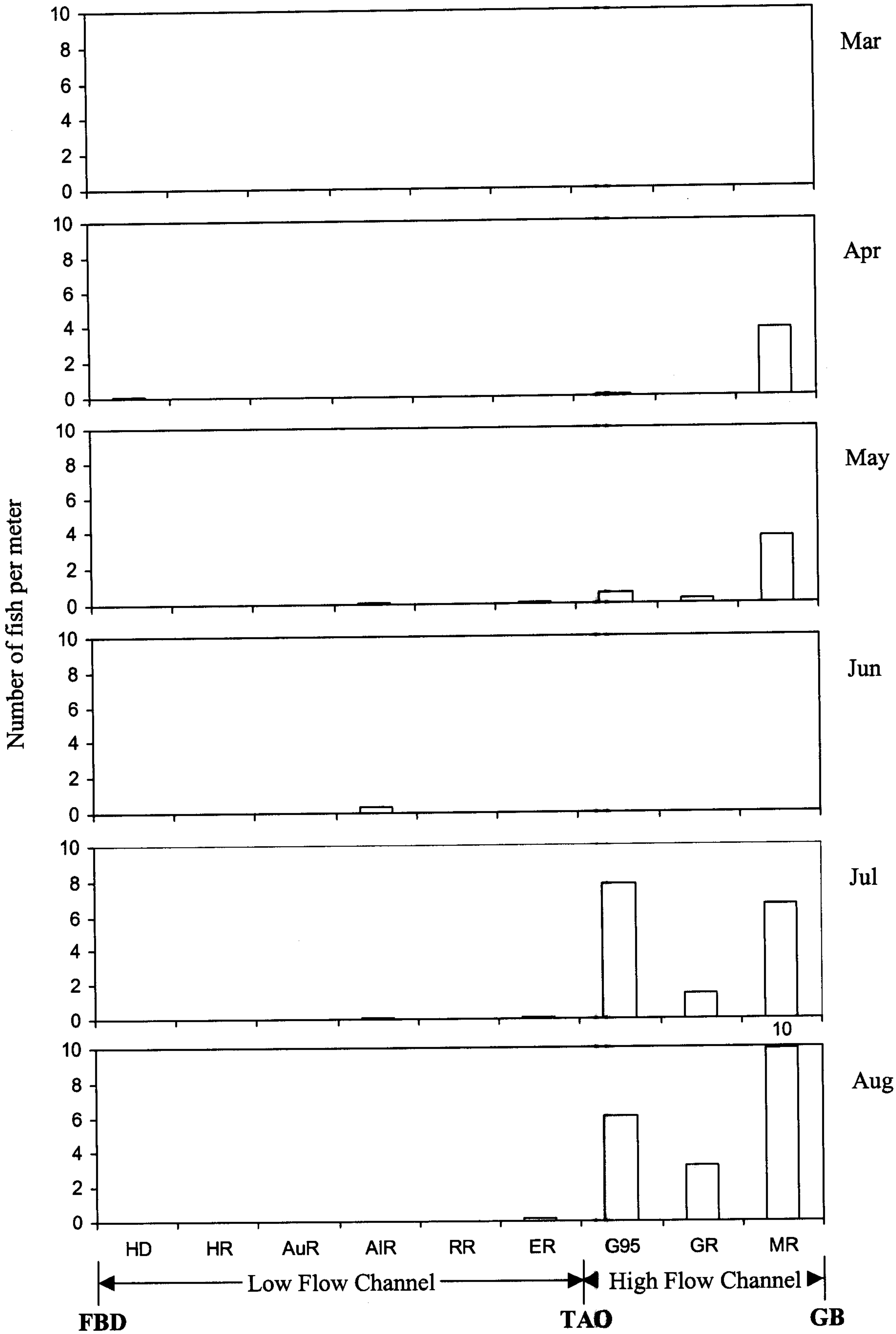

Figure 12. Seasonal abundance of native cyprinids at nine intermediate scale sites. Abundance is reported as the number of fish observed per linear meter of river bank.

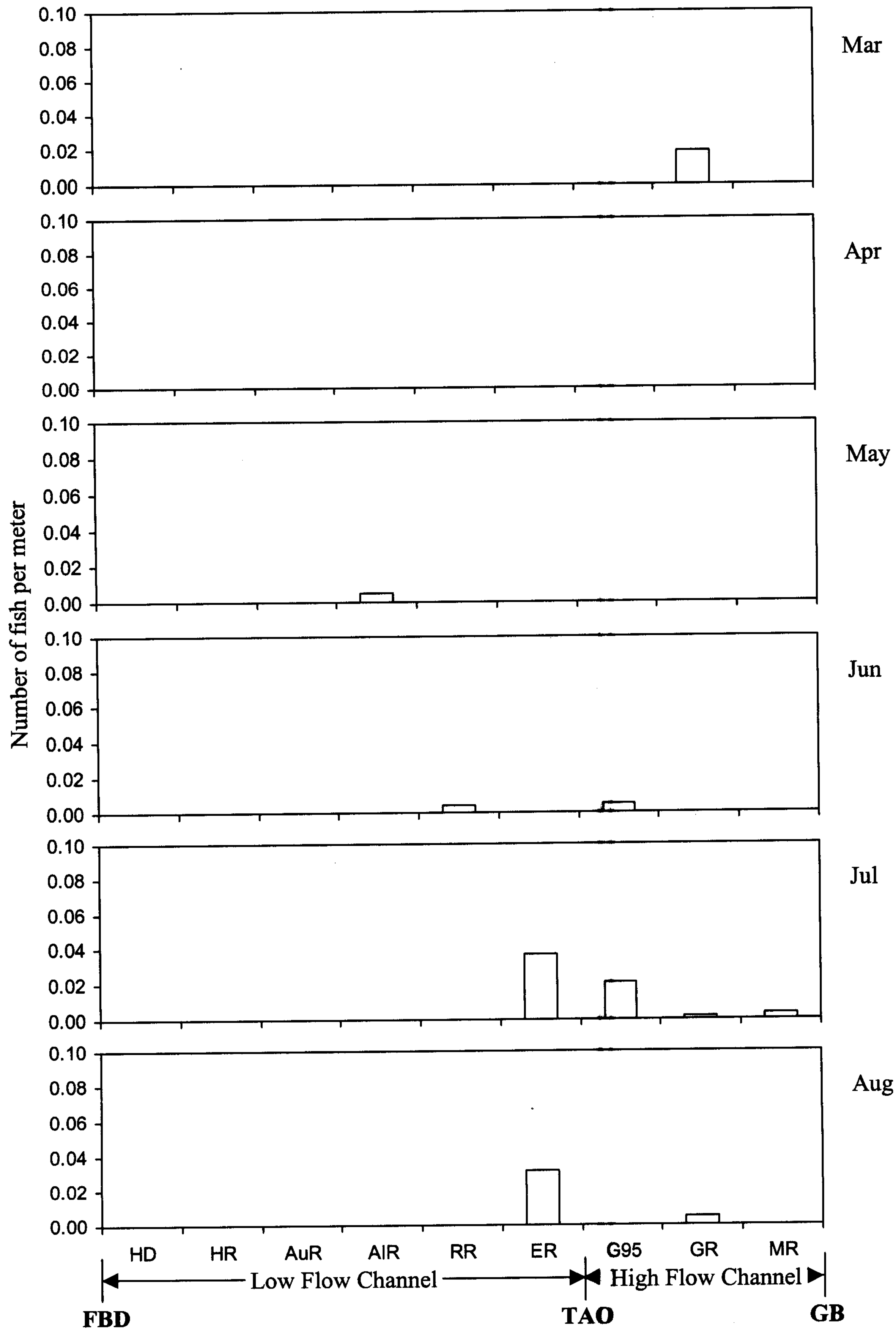

Figure 13. Seasonal abundance of centrarchids at nine intermediate scale sites. Abundance is reported as the number of fish observed per linear meter of river bank.

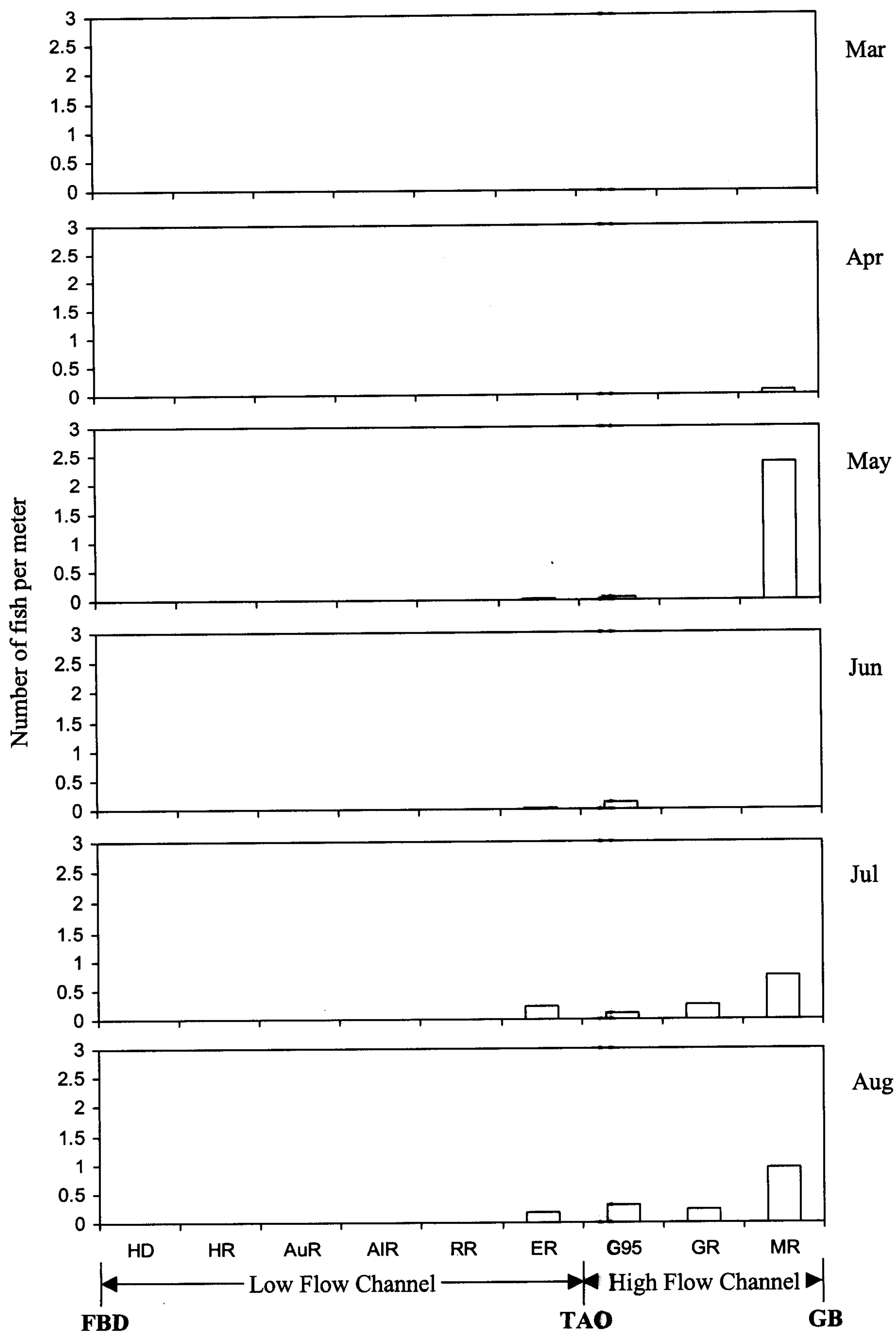

Figure 14. Seasonal abundance of tule perch at nine intermediate scale sites. Abundance is reported as the number of fish observed per linear meter of river bank.

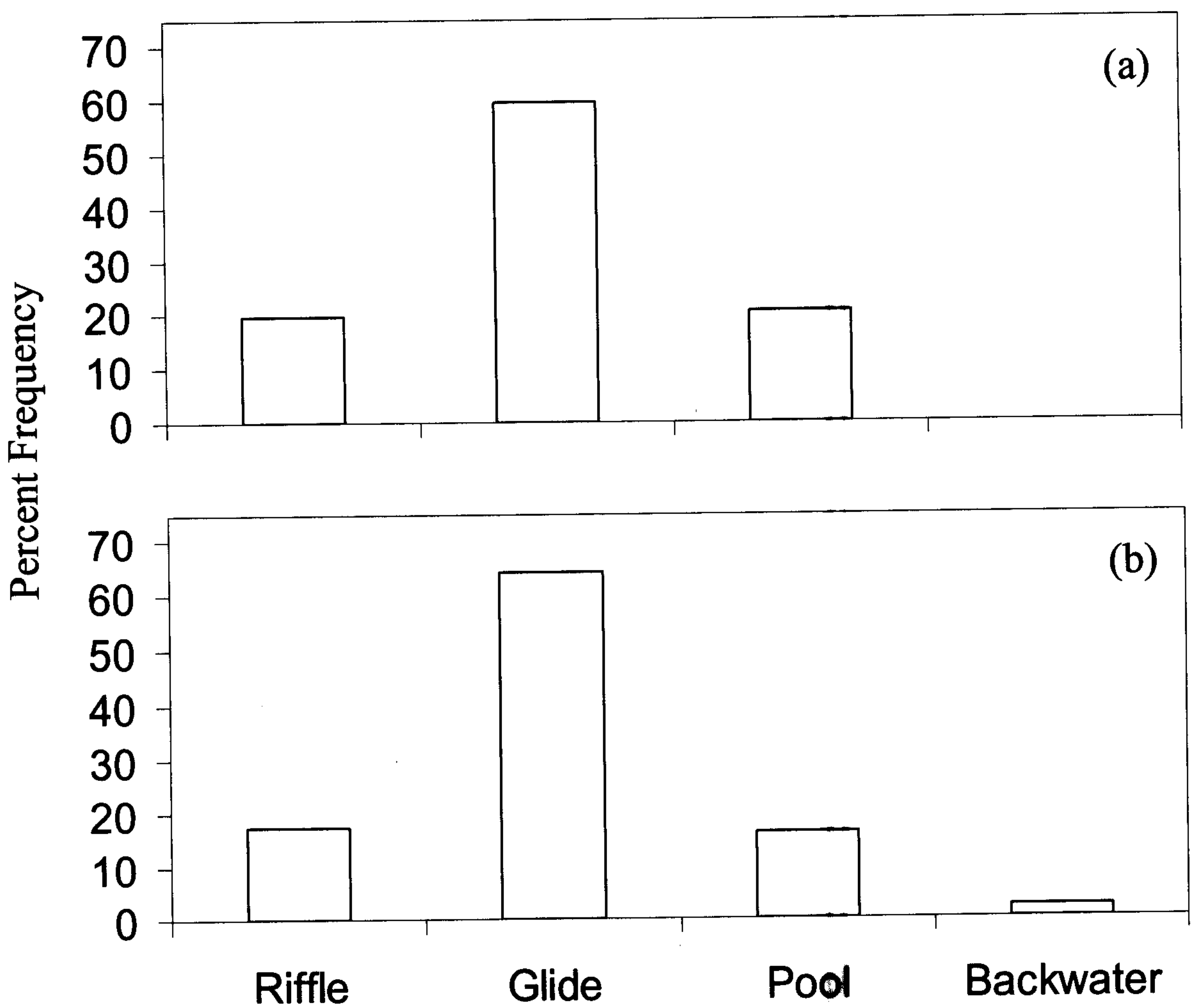

Figure 15. Hydrogeomorphic unit use by (a) age-0 steelhead, and (b) age-0 Chinook salmon.

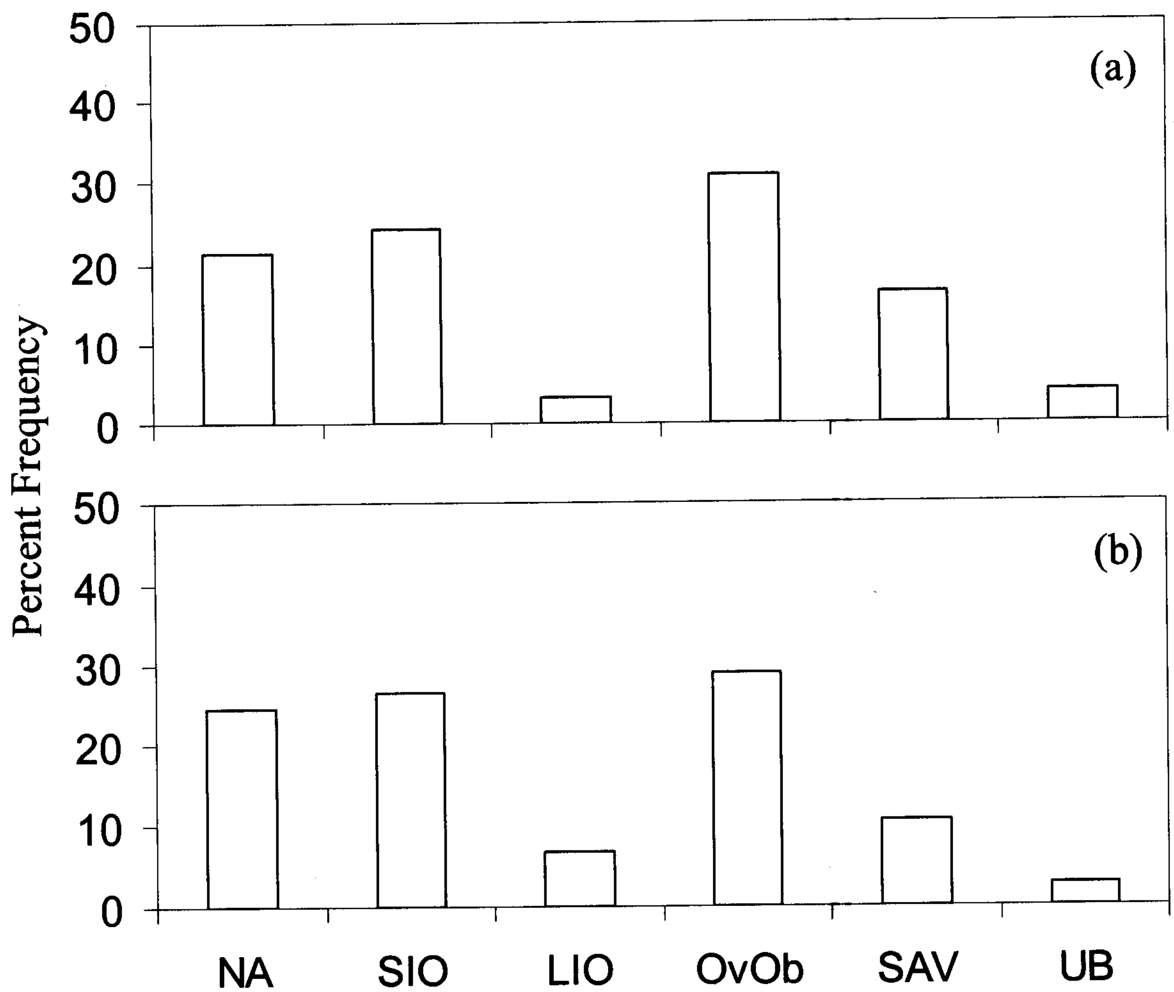

Figure 16. Cover use by (a) age-0 steelhead, and (b) age-0 Chinook salmon. None (no cover used), SIO (small instream objects), LIO (large instream objecst), OvOb (overbank object), SAV (submerged aquatic vegetation), UB (undercut banks).

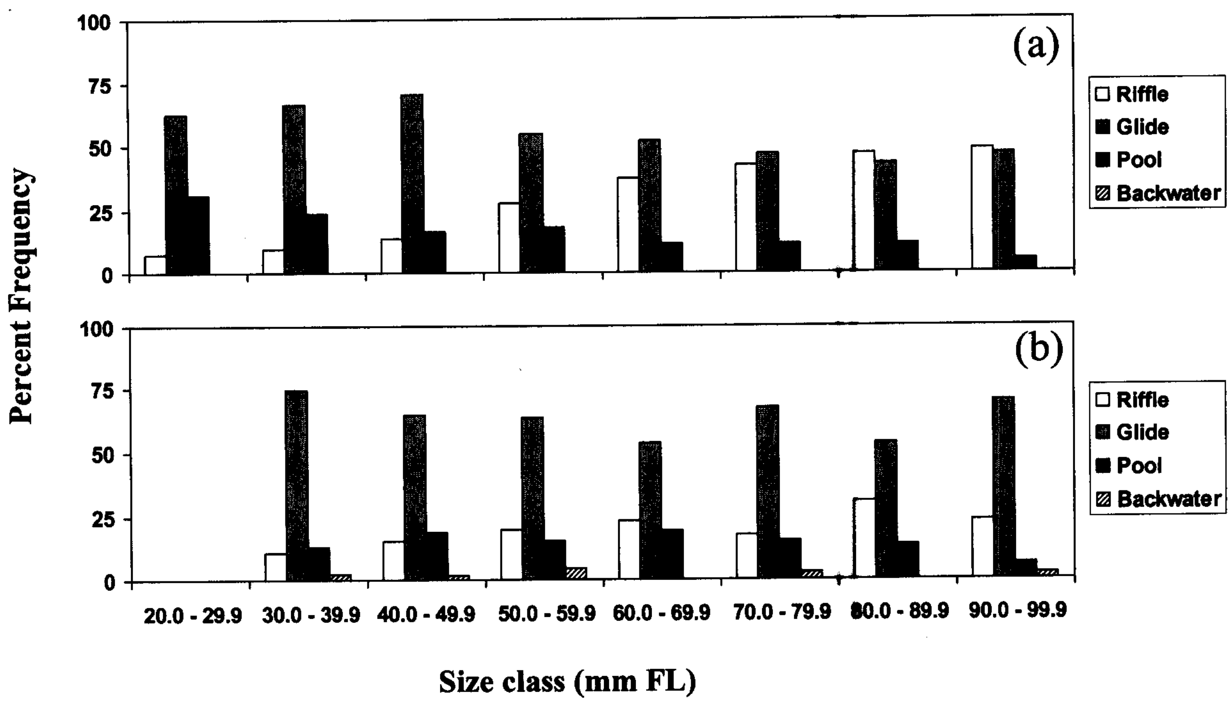

Figure 17. Hydrogeomorphic use by different size classes of (a) age-0 steelhead, and (b) age-0 Chinook salmon. There were no observations of Chinook salmon less than 30 mm FL.

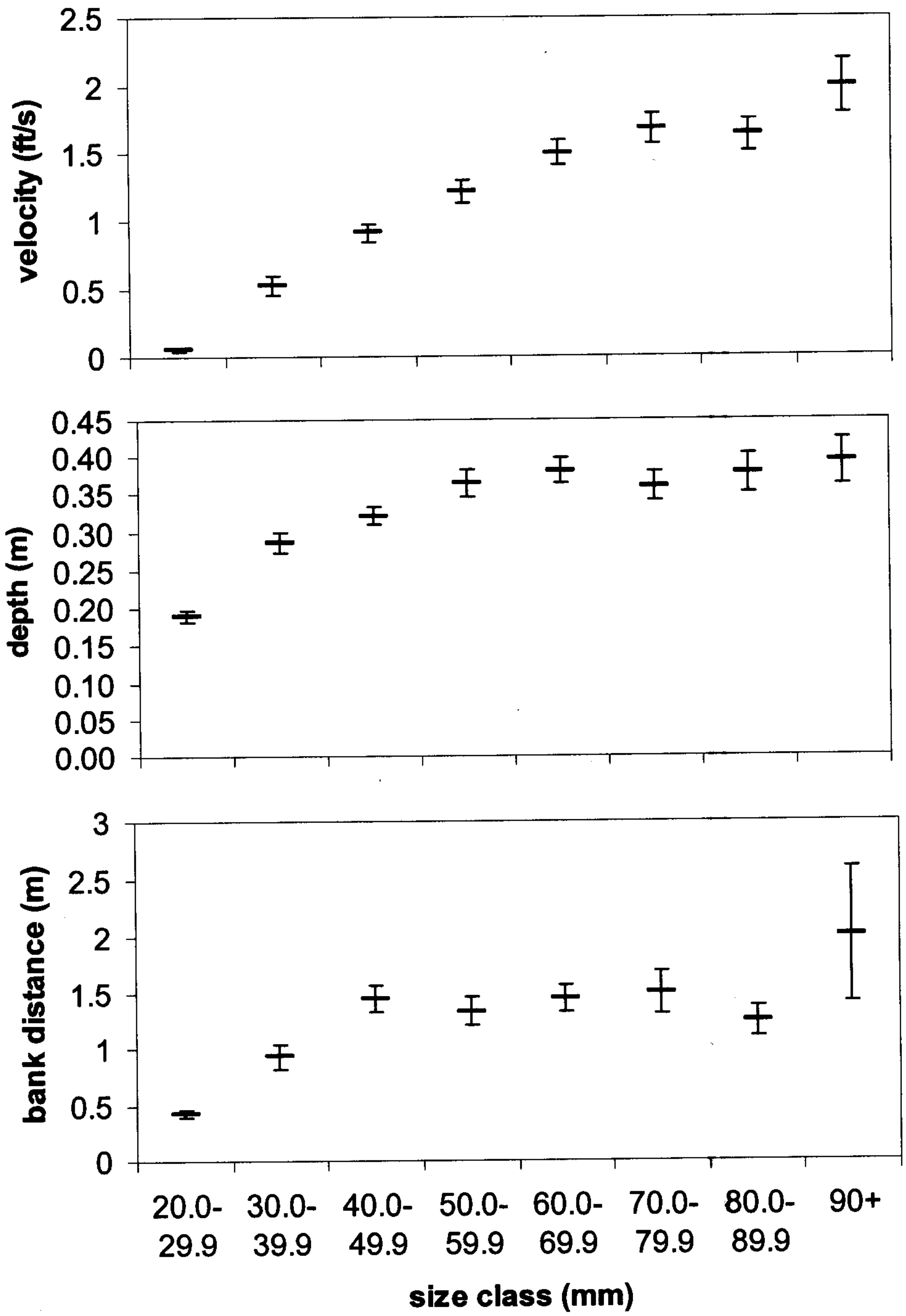

Figure 18. Average velocity, depth and distance from bank used by age-0 steelhead in various size classes. Errors bars represent standard deviation.

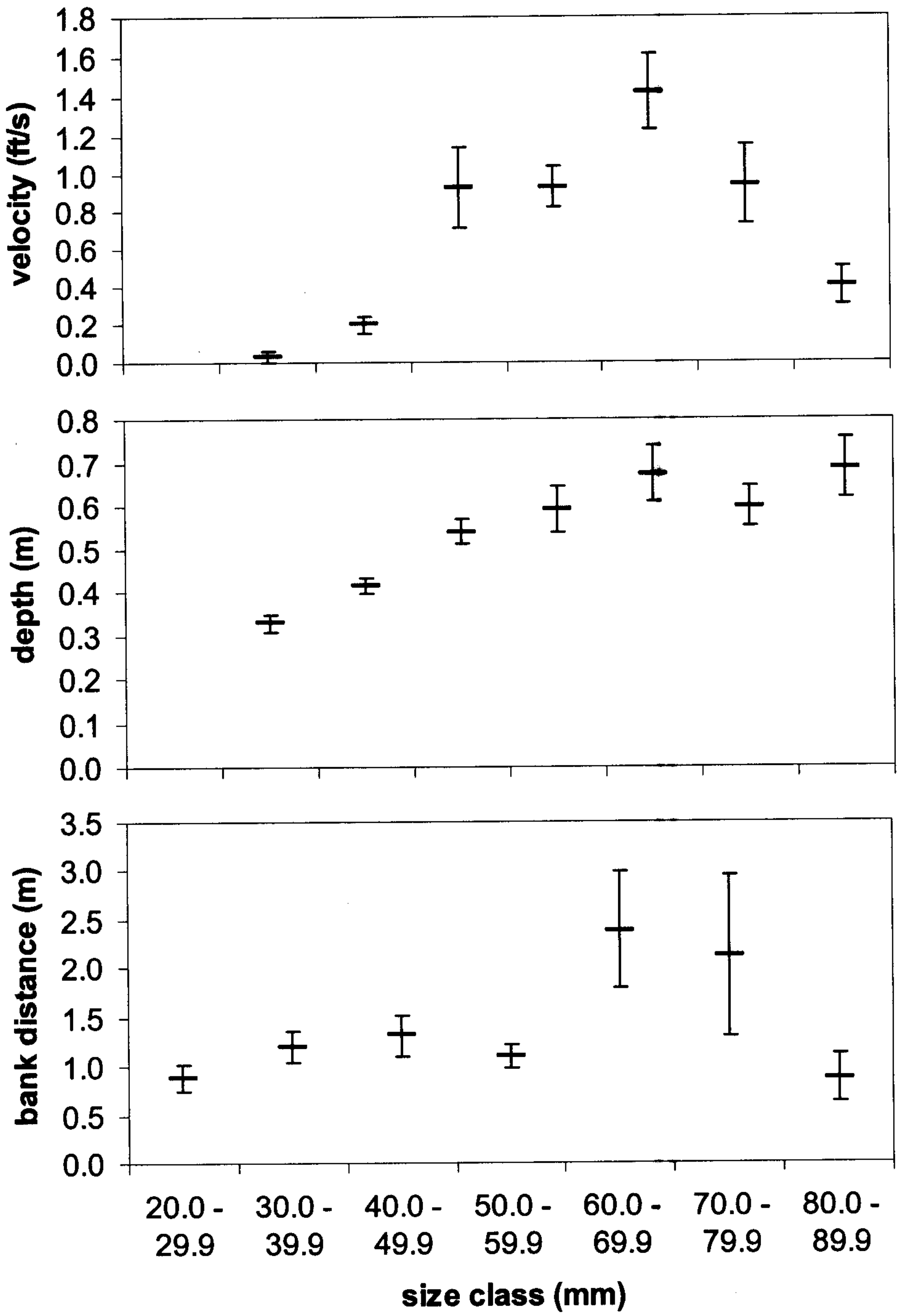

Figure 19. Average velocity, depth and distance from bank used by age-0 Chinook salmon in various size classes. Errors bars represent standard deviation.

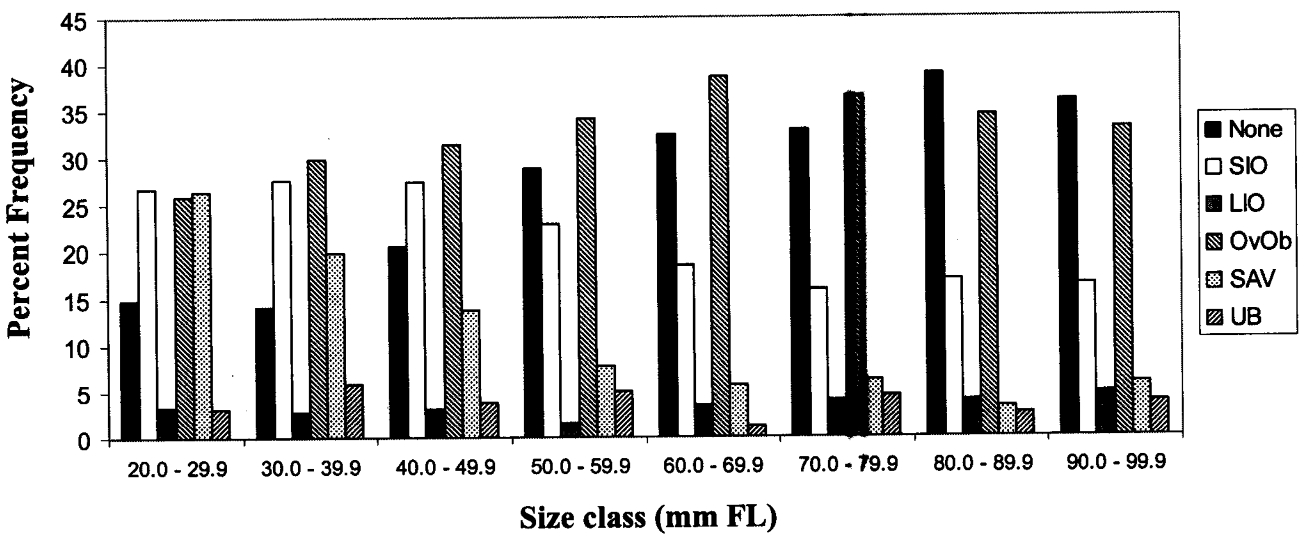

Figure 20. Cover use by various size classes of age-0 steelhead. The percent frequency of use was determined by dividing the number of observations associated with each habitat type by the total number of fish observations within each size class.

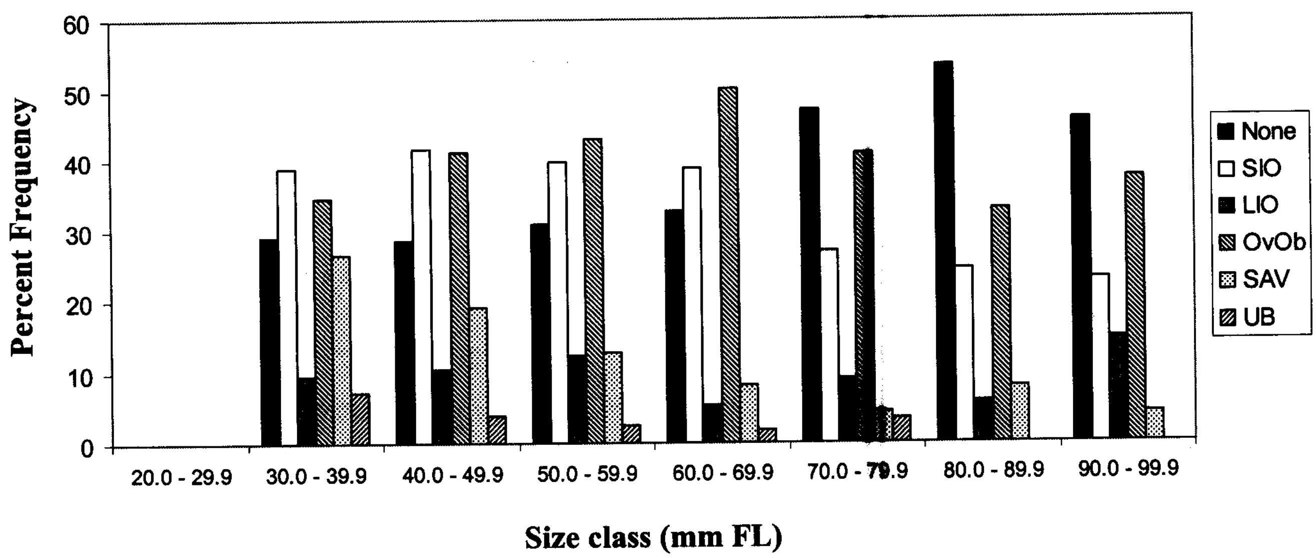

Figure 21. Cover use by various size classes of age-0 Chinook salmon. The percent frequency of use was determined by dividing the number of observations associated with each habitat type by the total number of fish observations within each size class.

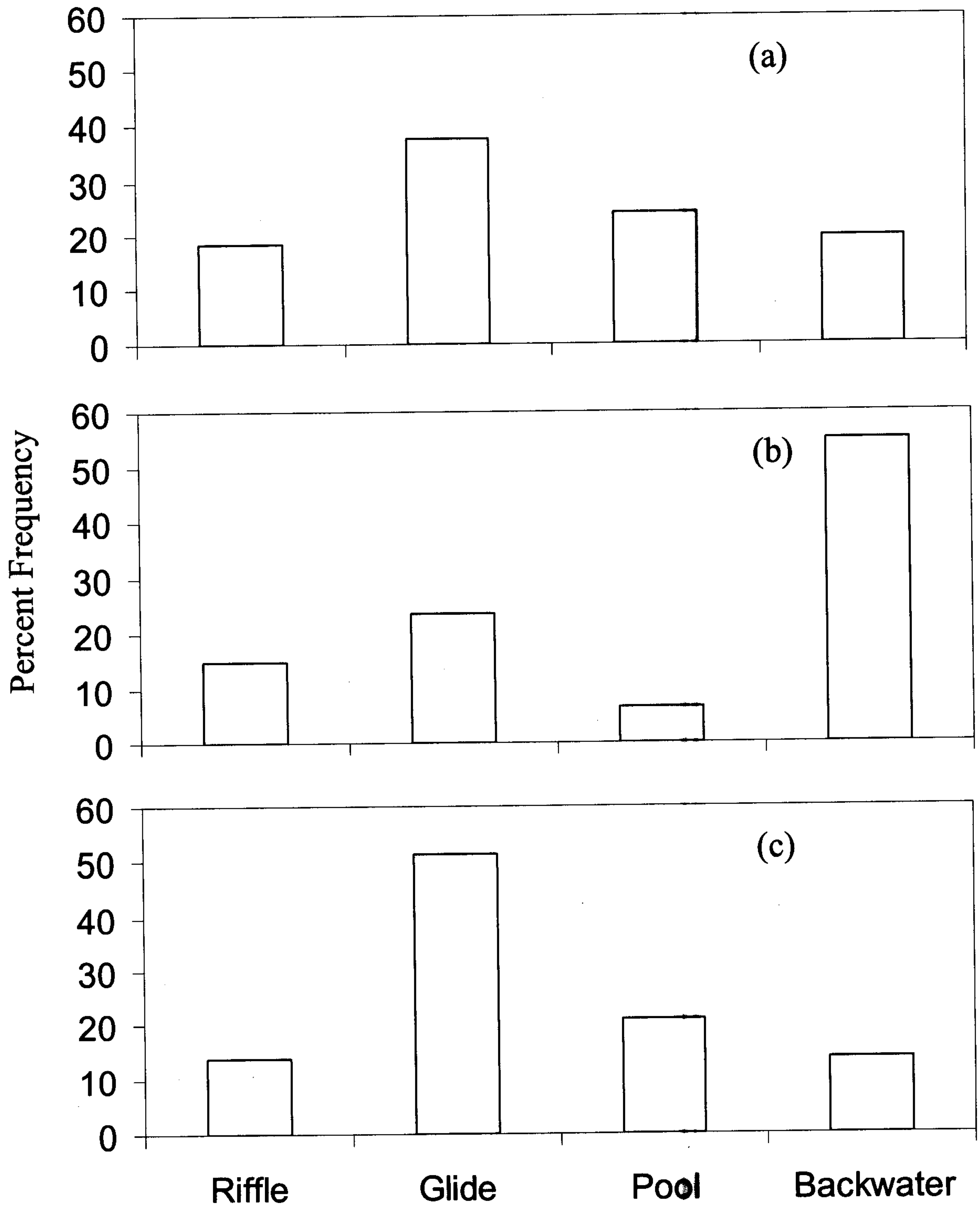

Figure 22. Hydrogeomorphic unit use by (a) cyprinids, (b) centrarchids, and (c) tule perch.

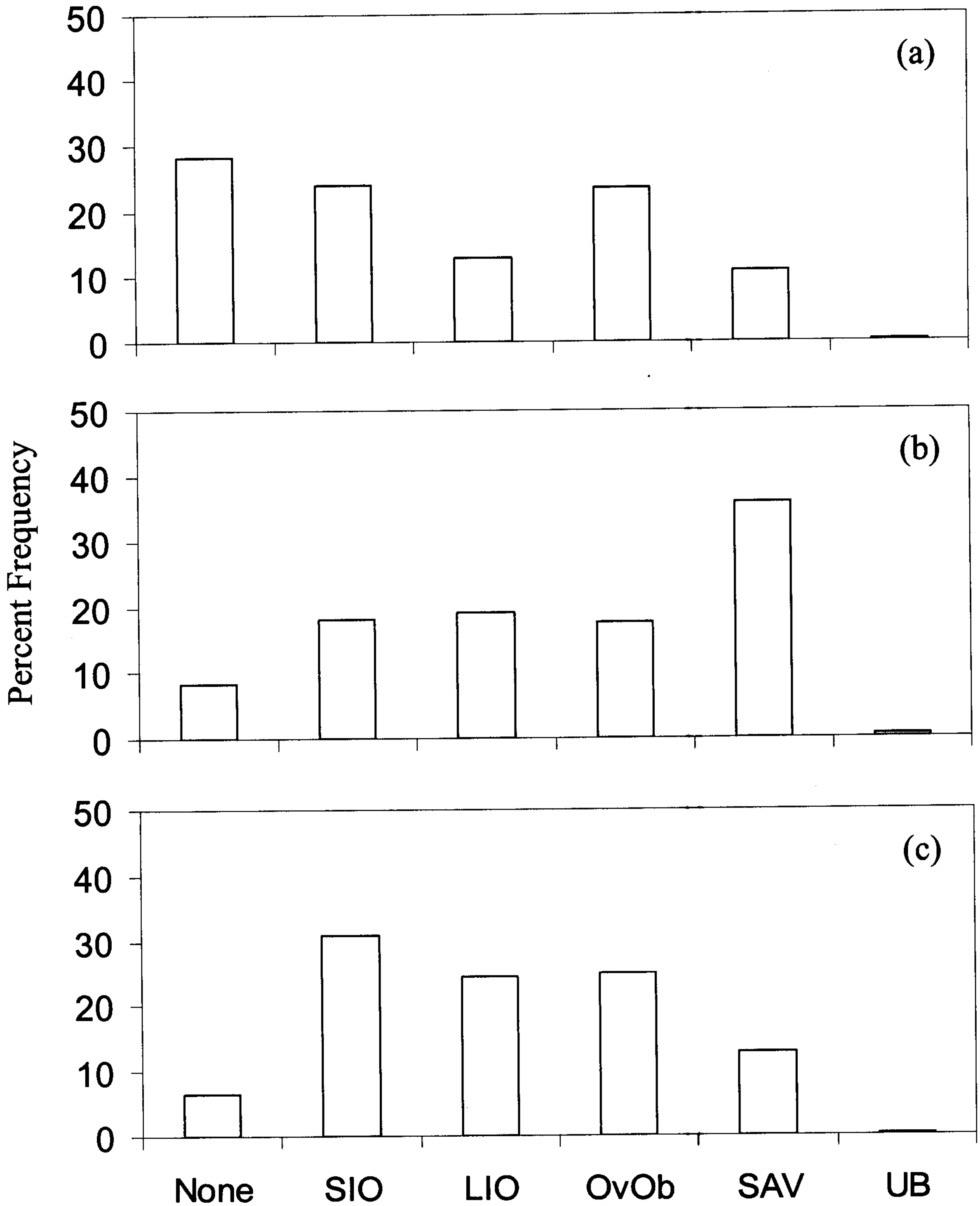

Figure 23. Cover use by (a) cyprinids, (b) centrarchids, and (c) tule perch.
None (no cover used), SIO (small instream objects), LIO (large instream objecst), OvOb (overbank object), SAV (submerged aquatic vegetation), UB (undercut banks).

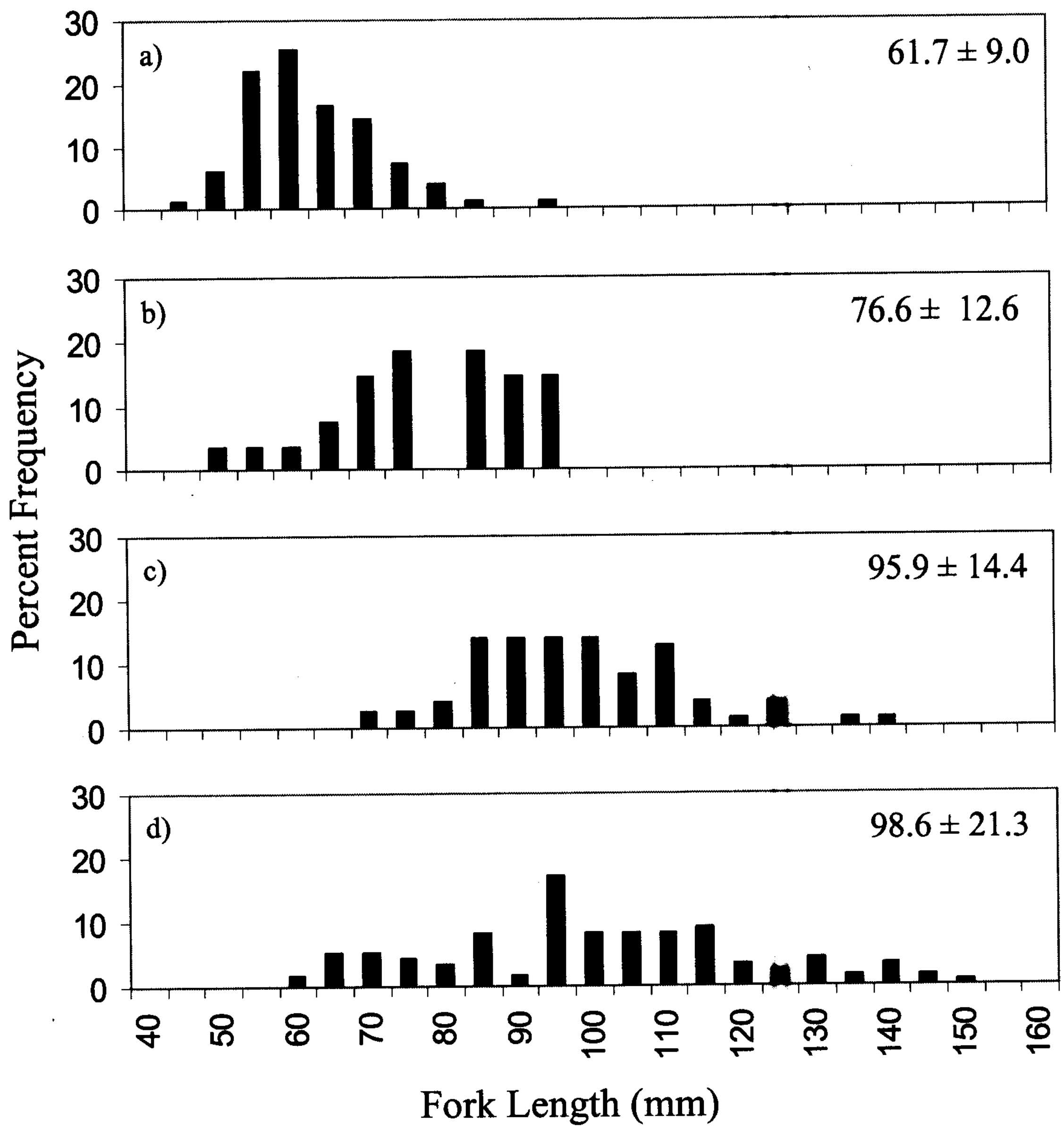

Figure 24. Length frequency distributions for steelhead captured as part of 2002 summer seining survey. Figures are ordered from upstream to downstream: a) Hatchery Ditch, b) Bedrock Park, c) Matthews Riffle, and d) Steep Riffle. Mean fork length and standard deviation listed in upper right corner.

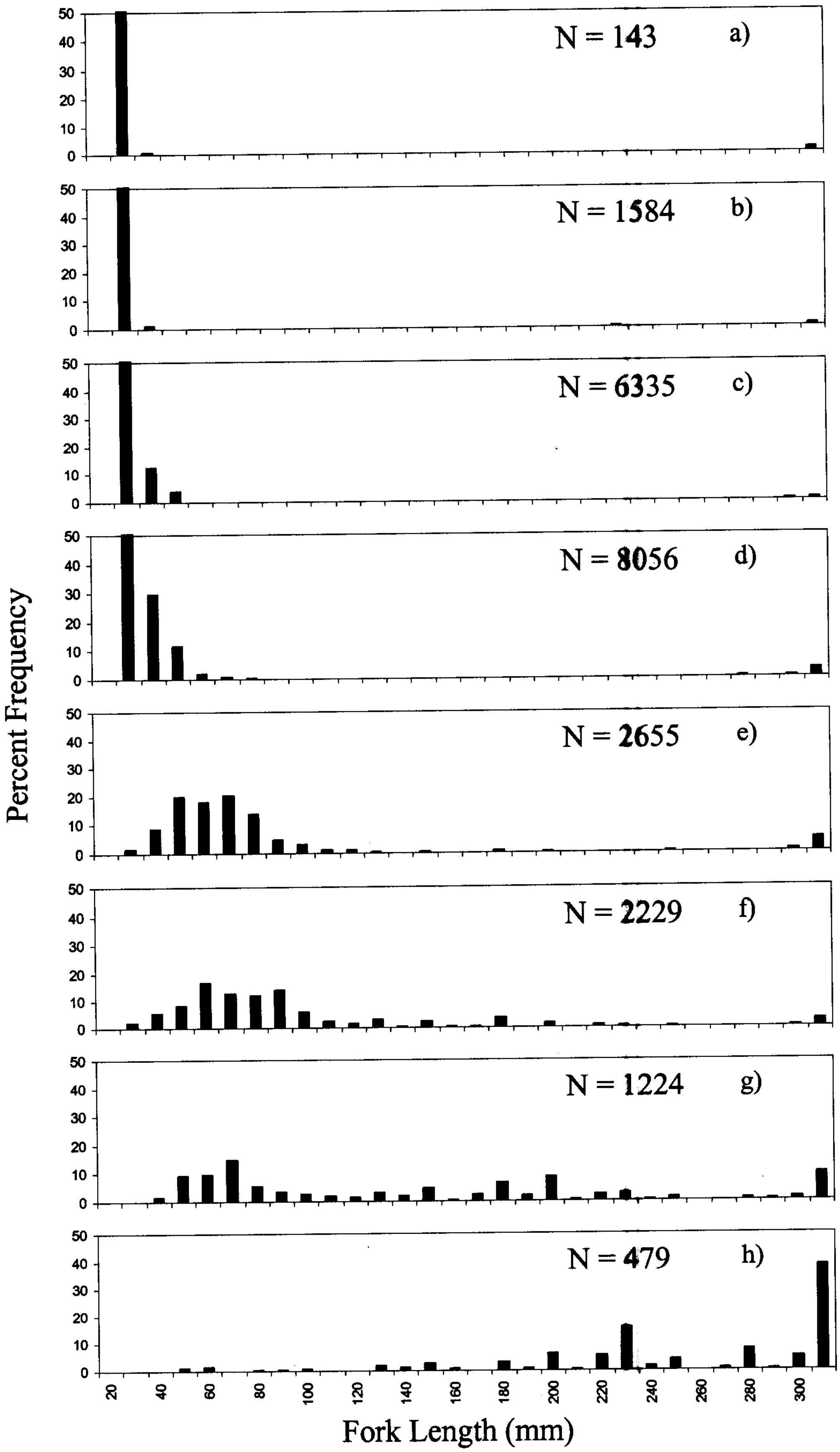

Figure 25. Length frequency distributions by month pooled for all survey years.